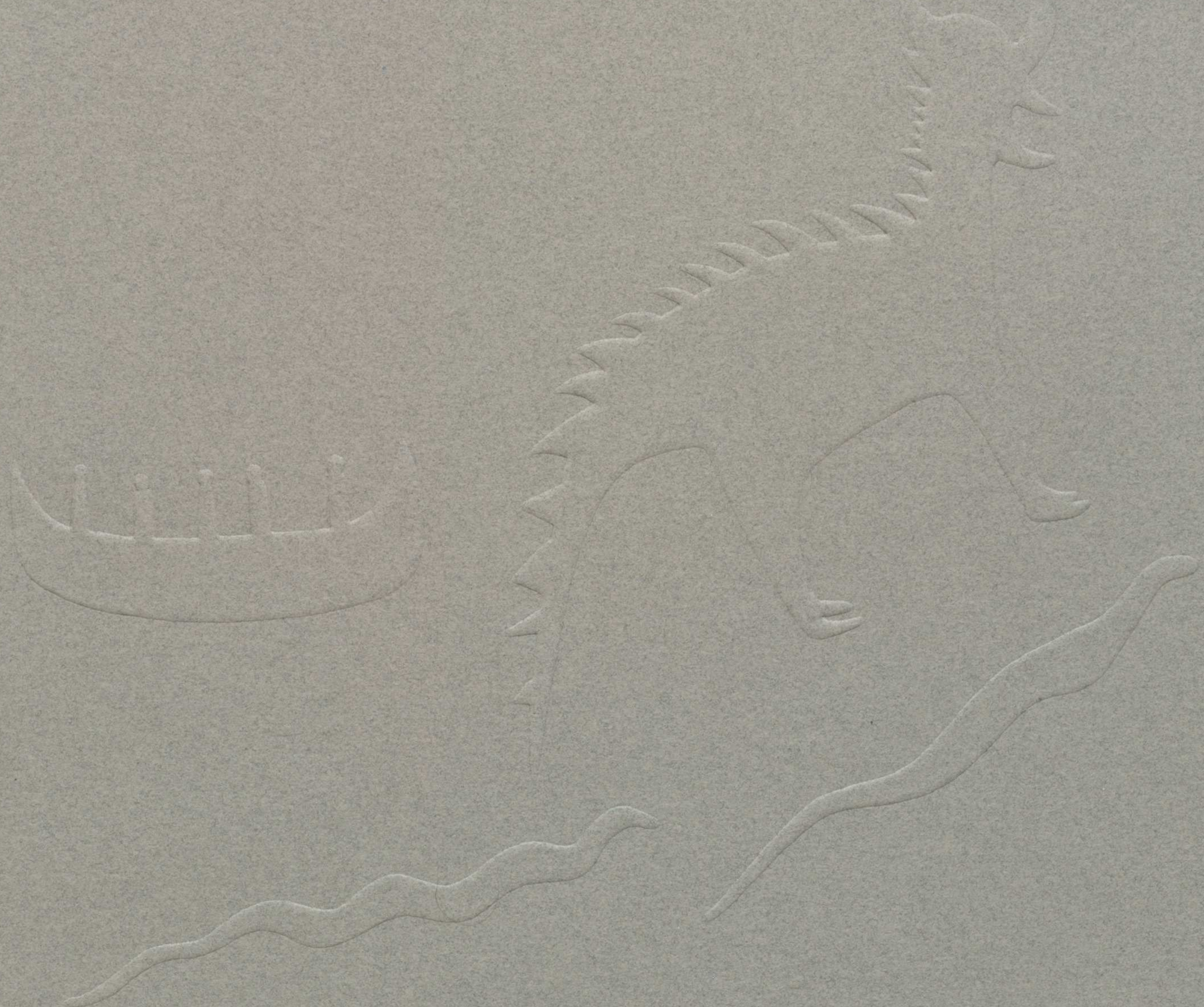
1993-08-01

Strategy for Virtual Elimination of Persistent Toxic Substances. Volume 1. Report of the Virtual Elimination Task Force to the International Joint Commission

International Joint Commission. Virtual Elimination Task Force

A STRATEGY FOR VIRTUAL ELIMINATION OF PERSISTENT TOXIC SUBSTANCES

Volume 1



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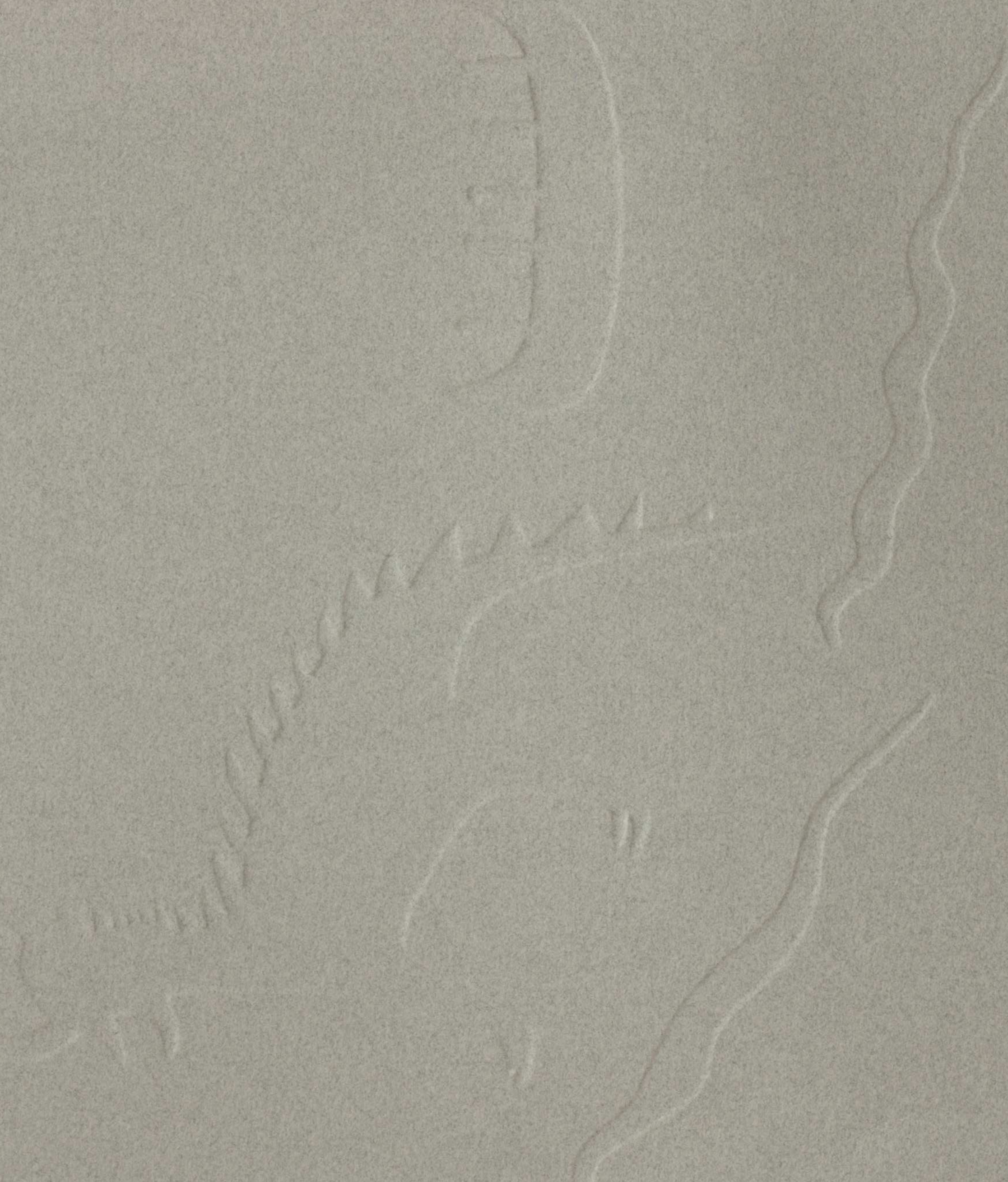

Colour photo and cover embossing

The photo illustrates a small portion of the rock paintings at the Agawa site on the north shore of Lake Superior. These paintings were reproduced on bark in the first half of the nineteenth century by an Ojibwa named Chingwauk. According to Chingwauk's explanation of the drawings, the mythical horned creature is Misshipeshu, the Great Panther or Lynx, who was the Great King of the Fishes; the serpents are representations of Mishikenahbik the Snake manitou; and to the left is a canoe containing five men. The drawings are part of a story involving a shaman called Myeengun (Wolf) who undertook a hazardous voyage, very likely in response to a vision.

A STRATEGY FOR VIRTUAL ELIMINATION OF PERSISTENT TOXIC SUBSTANCES

Volume 1

REPORT OF THE

VIRTUAL ELIMINATION TASK FORCE

TO THE

INTERNATIONAL JOINT COMMISSION

Windsor, Ontario

August 1993

ISBN 1-895085-65-9

Printed in Canada on recycled paper

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"IT'S NOT EASY BEING GREEN"

Kermit the Frog

PREFACE

The International Joint Commission charged its Virtual Elimination Task Force to investigate the requirement of the amended Great Lakes Water Quality Agreement to virtually eliminate the input of persistent toxic substances into the Great Lakes Basin Ecosystem. The Task Force was constituted in July 1990 and presented its initial advice and recommendations to the Commission a year later, in July 1991 (1).

In this Final Report, the Task Force:

- Presents a conceptual framework for a virtual elimination strategy.
- Presents its evaluation of the various elements comprising the strategy.
- Examines application of the strategy to three examples -- PCBs, mercury, and chlorine as a feedstock -- from which general principles can be gleaned, to apply to other persistent toxic substances.

The Task Force believes its advice to the Commission provides a firm basis for the Commission's advice, in turn, to governments regarding virtual elimination of the input of persistent toxic substances to the Great Lakes Basin Ecosystem.

The members, each of whom served in his or her personal and professional capacity, were drawn from a range of professional disciplines and possessed a variety of skills and experiences. Together, they contributed a wide spectrum of views on the virtual elimination issue. This diversity enhanced the Task Force's investigation, as members came to appreciate the different perspectives of their colleagues. The Task Force believes this diversity contributed to the strength of this Final Report.

The Task Force developed its advice through various means, including extensive deliberations among its multidisciplinary membership; interaction with other initiatives; information developed by contractors, Commission staff, workshops, and surveys; Commission-sponsored roundtables; and direct public input. To prepare its interim report, the Task Force held two public workshops, and that interim report was the subject of two additional workshops, held in conjunction with the Commission's 1991 Biennial Meeting in Traverse City, Michigan. For this Final Report, the Task Force expanded the scope of its public interface to obtain input not only from the general public but also from various interests that could be more directly impacted by the Task Force's findings, advice, and recommendations. The intent was to ensure that the advice in this Final Report is properly focused and will be used, i.e. based on reality and practicality.

Almost 3,000 copies of the draft Final Report were distributed for public review and comment in early April 1993. Between 80 and 120 people attended each of the three public workshops held in Milwaukee, Detroit, and Toronto on April 27, 28, and 29, 1993, respectively. In addition, almost 200 individuals or organizations provided written comments. Space precludes listing all who attended the workshops and/or provided written comments. The Task Force nonetheless gratefully acknowledges the advice received. Copies of the written comments and the transcript of the Toronto workshop are available on request.

The Task Force carefully considered all advice received and incorporated pertinent points into this Final Report. Reflecting the diversity and perspectives of its membership, the Task Force did not achieve consensus on all aspects of its deliberations. This contributed to healthy debate and better understanding of the complexities of the virtual elimination issue. One major aspect for which a strong difference of opinion emerged was chlorine. Some members contended that consideration of a feedstock chemical was not within the mandate of the Task Force. Rather, the charge was to develop a strategy to virtually eliminate persistent toxic substances, and that a focus on a feedstock chemical such as chlorine, which is not a persistent toxic substance *per sé*, would distract from the overall message of the report. Others felt equally strongly that chlorine was the significant common precursor of many persistent toxic substances and, thus, a good example to apply a virtual elimination strategy in a use tree context.

All members, however, wanted this report to focus on the charge from the Commission, i.e. to provide advice about what a virtual elimination strategy should contain and how such a strategy could be implemented. For this reason, views on application of the strategy are presented in Volume 2 for PCB, a "banned" substance; mercury, a substance with natural and anthropogenic sources; and chlorine, an example of a feedstock substance.

The Task Force gratefully acknowledges the assistance of all who contributed to its investigation and to this Final Report. These acknowledgements include the many contractors and colleagues who prepared background reports, which are listed at the

end of this volume; Dr. Eileen Choffnes; and Dr. Jeffery Foran. The Task Force was also ably supported by personnel in the Commission's Great Lakes Regional Office, notably David Dolan, Peter Boyer, Sally Cole-Misch, and Mike Gilbertson. Particular thanks are extended to Mary Ann Morin for preparing the manuscript in its many iterations, to Sally Cole-Misch for editing, and to Bruce Jamieson for attending to production details, including design and layout. For additional information, please contact the Task Force secretary, Dr. Marty Bratzel.

Although submission of this Final Report concludes the Task Force's mandate, the Commission welcomes, at any time, insight about the Agreement's virtual elimination requirement.

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BACKGROUND

1. THE ISSUE AND THE INVESTIGATION

1.1 THE AGREEMENT AND PERSISTENT TOXIC SUBSTANCES

The Parties' stated purpose for the 1978 Great Lakes Water Quality Agreement "is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." In particular, the Parties undertook an obligation to virtually eliminate the input of persistent toxic substances. This commitment was strengthened by the 1987 amendments to the Agreement. Article II of the Agreement states that "It is the policy of the Parties that ... The discharge of toxic substances in toxic amounts be prohibited and the discharge of any or all persistent toxic substances be virtually eliminated."

Specifically with regard to persistent toxic substances, the intent is to undertake actions, programs, and other measures to:

- Protect human health.
- Ensure the continued health and productivity of living aquatic resources, including their use by humans.
- Ensure further ecosystem protection.

To fulfill these requirements, it is necessary to:

- Virtually eliminate present inputs of persistent toxic substances.
- Anticipate and prevent future inputs and problems.
- Remediate problems from past and present inputs.

1.2 THE COMMISSION AND PERSISTENT TOXIC SUBSTANCES

For more than a decade, the Commission, as it has tracked the Parties' progress, has become increasingly vocal in its concern with regard to persistent toxic substances. In its *Fifth Biennial Report* (2), the Commission urged the Parties to

> "take every available action to stop the inflow of persistent toxic substances into the Great Lakes environment."

Specifically, the Commission recommended that

> "the Parties complete and implement immediately a binational toxic substances management strategy ... for accomplishing, as soon as possible, the Agreement philosophy of zero discharge."

These recommendations were made on the basis of a number of important conclusions that the Commission reached in the course of its research and analysis. It became clear to the Commission that concern for fish and wildlife health was well founded, and that this concern should be extended to humans as well. Thus, it was concluded that

> "What our generation has failed to realize is that, what we are doing to the Great Lakes, we are doing to ourselves and to our children."

and

> "... the Commission must conclude that there is a threat to the health of our children emanating from our exposure to persistent toxic substances, even at very low ambient levels."

The Commission based these conclusions and recommendations on mounting evidence which, it concluded, " ... cannot be denied." In its *Sixth Biennial Report* (3), the Commission concluded that

> "because persistent toxic substances remain in the environment for long periods of time and become widely dispersed, and because they bioaccumulate in plants and animals -- including humans -- that make up the food web, the ecosystem cannot assimilate these substances."

and thus they

> "are too dangerous to the biosphere to permit their release in any quantity."

Further,

> "the presence and impact of persistent toxic substances on all sectors of the ecosystem ... defies boundaries and is not easily resolved through traditional technologies and regulations. ... These substances cross jurisdictional, geographic and disciplinary lines that have tended to circumscribe previous efforts to restore and protect the ecosystem.... There are no preordained boundaries in the way the natural system functions and in how humans interact with and within it."

The Commission concluded that, despite the Agreement requirement to virtually eliminate the input of persistent toxic substances to the Great Lakes basin and to protect human and environmental health,

> "we have not yet virtually eliminated ... any persistent toxic substance."

The Commission observed therefore that, as part of the solution,

> "[do] we ... want to continue attempts to manage persistent toxic substances after they have been produced or used, or [do] ... we want to ... eliminate and prevent their existence in the ecosystem in the first place. ... Since it seems impossible to eliminate discharges of these chemicals ..., a policy of banning or sunsetting their manufacture, distribution, storage, use and disposal appears to be the only alternative."

1.3 THE COMMISSION'S CHARGE TO THE TASK FORCE

In its *Fifth Biennial Report* (2), the Commission urged Governments to develop and implement

> "a comprehensive, binational program to lessen the use of, and exposure to persistent toxic chemicals found in the Great Lakes environment."

The Commission recognized (3), however,

> "that problems associated with persistent toxic substances cannot be simply defined or solutions easily implemented."

To contribute to the definition and resolution of the issue, the Commission charged the Virtual Elimination Task Force to investigate the Agreement requirement to virtually eliminate the input of persistent toxic substances into the Great Lakes Basin Ecosystem. Specifically, the Task Force was charged to provide advice and recommendations to the Commission about what a virtual elimination strategy should contain and how the strategy could be implemented. The Commission will, in turn, provide its advice to Governments.

1.4 THE TASK FORCE'S POINT OF DEPARTURE

The Commission specifically charged the Task Force to focus on **persistent** toxic substances, rather than toxic substances. Also, the Task Force was not asked to investigate whether persistent toxic substances have caused injury. The virtual elimination commitment incorporated by the Parties into the Agreement in 1978, and the stance taken by the Commission in its *Fifth* and *Sixth Biennial Reports* (2,3) support the conclusion that the evidence is more than sufficient to advocate for virtual elimination of the input of persistent toxic substances. The members of the Task Force, individually and as a whole, accepted that some problems remain with persistent toxic substances; the question is, how to resolve those problems.

The Task Force recognized that the Commission's call for far-reaching action requires clear evidence that damage has occurred and continues to occur, and that persistent toxic substances are among the causes of this injury. Only with strong evidence will there be a stimulus for development of, and the timely commitment to implement a virtual elimination strategy and thereby eliminate or prevent resultant injurious effects to health and the ecosystem.

Since the Commission's *Fifth Biennial Report*, issued in 1990, the evidence has continued to mount. Important scientific and government consensus has emerged to further cement the basis for the Commission's conclusions and position described above. Specifically, the Task Force observed that there is broadened understanding and acceptance that:

- A number of human-made persistent toxic substances have and continue to cause significant adverse effects on, and substantial damage to, fish and wildlife species.
- Persistent toxic substances are a threat to human health, to fish and wildlife health and, indeed, to the entire ecosystem.

In addition, adverse effects have been reported in the children of women who ate contaminated fish from Lake Michigan, and the reported injury occurred mainly prenatally.

Therefore, as a crucial component of this report, the Task Force reviewed evidence and conclusions developed by knowledgeable experts in various scientific disciplines and published in the peer-reviewed literature. Appendix D provides perspective about the injury caused by some persistent toxic substances, and the danger they pose. A brief summary is provided below.

1.5 THE INJURY

There is general agreement that several contaminants routinely found in the Great Lakes basin already meet the definition of a persistent toxic substance (see Chapter 2). Despite considerable environmental improvement (discussed later in this chapter), long-term exposure to these contaminants presents a continuing threat to the health of the ecosystem and to the life that constitutes it. A focused strategy, together with a concerted effort, are required to virtually eliminate inputs of persistent toxic substances **to** the ecosystem, so as to virtually eliminate their presence **in** the ecosystem and to eliminate impairment of ecosystem health. A strategy is also required to protect the ecosystem by preventing future inputs of persistent toxic substances, prior to their introduction into use.

In 1985, the Commission's Great Lakes Water Quality Board identified 11 Critical Pollutants (Table 1) that are persistent, bioaccumulate in living organisms, cause adverse human and environmental health effects, and have been subject to extensive regulation (4). However, actions to date are insufficient and incomplete. For example, bans or use restrictions for PCBs and some chlorinated hydrocarbon pesticides are not absolute.

- It is estimated that more than 50% of all PCBs ever produced are still in use. Loadings continue from a variety of known and unknown sources.

- Many bans or restrictions on pesticides (such as DDT, dieldrin, endrin, aldrin, chlordane, toxaphene, heptachlor, and mirex) apply only to domestic uses and may not come into effect until existing stocks are depleted. Thus, commercial products containing many of these pesticides are still for sale in Canada and the United States. This includes DDT, which can still be purchased despite a 1990 ban on its sale. Further, large quantities of banned or restricted pesticides are still produced in the United States and exported (5-7).

Continued production, sale, use, and/or export provides numerous opportunities for release to the environment and, ultimately, additional inputs to the Great Lakes. Because inputs continue, persistent toxic substances still pervade the ecosystem and its food chain at levels sufficient to cause injury.

Fish, particularly the predators at the top of the food chain, are excellent indicators of ecosystem health because they bioaccumulate and biomagnify many aquatic contaminants. Birds and other wildlife (such as mink and otter) that eat fish display a wide range of contaminant-related problems, including population decrease, effects on reproduction, eggshell thinning, behavioural changes, biochemical change, and increased mortality (see Table D-2).

The adverse reproductive and developmental effects observed in wildlife may foreshadow human population effects. Wildlife may be the "canary in the coal mine," warning of a potential blight on present and future generations. There are few comprehensive studies of such effects on humans but, given effects in Great Lakes wildlife, some researchers are now focusing on possible human health effects. Generally, for a number of persistent toxic substances, an association has been made between human body burdens and the regular inclusion of fish in the diet.

Table 1
Critical Pollutants Identified by the Water Quality Board

- Total polychlorinated biphenyls (PCB)
- DDT and metabolites
- Dieldrin
- Toxaphene
- 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)
- 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF)
- Mirex
- Mercury
- Alkylated lead
- Benzo(a)pyrene
- Hexachlorobenzene

Source: Reference (4).

- One study in Michigan demonstrated that sport anglers who ate Great Lakes fish (especially trout and salmon) had higher blood and tissue levels of PCBs than individuals who seldom or never ate such fish (8).

- A 1993 report (9) identified an association between blood levels of DDT/DDE and breast cancer, and an elevated (but not statistically significant) risk of breast cancer associated with PCBs.

- There is suggestive evidence from another study that women who ate several meals of Lake Michigan fish a month for at least six years preceding their pregnancies bore children who had lower birth weights, shorter gestational periods, and smaller head circumferences at birth, and who showed discernible cognitive, motor, and behavioural deficits when tested later, compared to infants born to women who had not consumed Lake Michigan fish prior to or during their pregnancies. The discernible cognitive, motor, and behavioural effects persisted in tests at seven months and four years (5,10-19; see also Appendix D).

Physical growth and short-term memory deficits appear to be specifically related to *in utero* exposure. This concept of *in utero* injury to the unborn, due especially to persistent toxic substances that interfere with the extremely subtle and sensitive workings of endocrine systems, including sex steroid metabolism, is of profound consequence. In a recent consensus conclusion, a multidisciplinary group of experts stated that (20):

"The concentrations of a number of synthetic sex hormone agonists and antagonists measured in the U.S. human population today are well within the range and dosages at which effects are seen in wildlife populations. In fact, experimental results are being seen at the low end of current environmental concentrations."

This is consistent with a 1992 review (30) and a related 1993 study (21) where it is hypothesized that fetal exposure to estrogens or estrogenic chemicals (endocrine disruptors such as DDT, PCBs, dioxins, furans, and hexachlorobenzene, among other organochlorines and metals) may be responsible for declining sperm counts and a rising incidence of abnormalities in the human male reproductive tract.

Persistent toxic substance contamination has also injured the economy and society, through real and suspected human injury and health costs, real environmental costs, and loss of economic value, for example, as a result of the loss of commercial fisheries. Society has accumulated costs in the form of an "environmental deficit" -- a debt of problems, cleanup costs, and risks that are shifted to the future, and to society at large.

Taken as a whole, the weight of evidence accumulated over the past three decades indicates that exposures to persistent toxic substances are indeed associated with injury, disease, and death in a wide variety of life forms. In its *Sixth Biennial Report* (3), the Commission recommended that such an approach be applied "to the identification and virtual elimination of persistent toxic substances." The weight-of-evidence approach has been endorsed in the United States by the National Academy of Sciences and the Office of Science and Technology Policy, and has been widely adopted by numerous government regulatory agencies for the evaluation of scientific information (22,53).

The weight-of-evidence approach assists scientists and others in answering the question: "Is the available information sufficient to conclude that the observed or predicted phenomenon will lead to an adverse effect in humans or aquatic life?" The approach considers the full spectrum of relevant factors, both positive and negative, and gives appropriate weight to the scientific evidence on a case-by-case basis. For example, factors typically considered in evaluating the weight of evidence include the quality of data, the number of positive versus negative studies, species differences, relevance of animal data to humans, strength of association, mechanism of action, and other relevant data.

Although evidence of injury is clear for some persistent toxic substances and there is ample justification to develop and apply a virtual elimination strategy to deal with them, doubt exists for a number of other substances, especially in regard to injury to future generations. In addition, there are different interpretations in regard to observed injury. Because of uncertainty, a precautionary approach is needed.

1.6 PROGRESS TO DATE

The Commission and the Task Force both recognize that considerable progress has been made to reduce inputs of persistent toxic substances to the Great Lakes Basin Ecosystem. As a result, ecosystem health today is improved from conditions 20 years ago. This is the direct result of several activities such as construction of municipal and industrial waste treatment systems, remedial efforts to mitigate contaminants already in the ecosystem, and restrictions, phaseouts, and bans on the manufacture and/or use of certain persistent toxic substances.

Early treatment methods focused on the control of traditional pollutants, such as phosphorus, biochemical oxygen demand, and suspended solids. This coincidentally reduced other contaminants, especially contaminants (many being persistent) that associated with the particulate phase of an effluent. More recently, releases of some persistent toxic substances have been reduced as a consequence of manufacturing process changes, and as the movement to reduce and phase out persistent toxic substances continues to gain momentum.

Appendix E lists and describes examples of specific technological changes, regulatory programs, and voluntary measures that account for the successes achieved, and that are emerging as possible vehicles for future delivery of virtual elimination. Many of these examples contain elements similar to those recommended for use as part of the virtual elimination strategy presented in Chapter 3 and, in particular, multistakeholder consultation and dialogue.

As a result of such measures, ecosystem concentrations of persistent toxic substances dropped markedly, especially during the late 1970s (see Figures E-1 through E-5). Collectively, these measures have contributed to increases in bird populations, reductions in bird malformities, and reduction in contaminants in fish tissue. In its *Sixth Biennial Report* (3), the Commission noted that

> "nesting pairs [of bald eagles] reintroduced to the north and south shores of Lake Erie continue to survive, which can be seen as evidence of improved ecosystem quality. The viability of many of their eggs also attests to improvements."

However, in many cases, contaminant concentrations have leveled off (see, for example, Figure E-1) and, in some cases, appear to be increasing (see Figure E-5). In addition, as discussed above, the actions taken to date, despite leading to significant improvement in ecosystem quality, are insufficient to eliminate biological injury. To illustrate, four bald eagles born in 1993 along the Michigan shoreline of the Great Lakes have life-threatening deformities: twisted beaks or clubbed feet. Two of the eagles were from Lake Erie nests. This is further stimulus to develop and implement a virtual elimination strategy.

1.7 THE TASK FORCE'S INVESTIGATION

In its investigation, the Task Force focused on the overall concept of a virtual elimination strategy and the specific components required to achieve and maintain a healthy ecosystem. In addition, the Task Force evaluated how virtual elimination can be achieved, and applied the strategy to three case examples. The Task Force has endeavoured to develop a strategy and advice that it believes is necessary and right. To accomplish this goal, the Task Force investigated not only the input of persistent toxic substances **to** the ecosystem, but also their presence **in** the ecosystem. To ensure the credibility of its work with a wide spectrum of stakeholders and to provide a fair assessment, the Task Force attempted to maintain a fair, open-minded, nonpartisan perspective.

Specifically, the Task Force focused on:

- What injuries have persistent toxic substances caused, and what danger do they pose?

- Definitions of key terms -- including persistent toxic substance, virtual elimination, and zero discharge -- to ensure a common and clear basis for discussion and understanding.

- Selection criteria and a procedure to develop a framework within which to identify chemicals that would be subject to the virtual elimination strategy.

- Sources and uses of persistent toxic substances. Where are they found in commerce? How do they enter and move within the ecosystem? What is their fate in the ecosystem? What are the quantities associated with the various sources and uses, and what level of concern should be placed on the location and movement of persistent toxic substances in the ecosystem?

- Evaluation of the legislative, regulatory, technological, economic, and educational tools and opportunities to achieve virtual elimination.

- Identification of performance indicators, or measures of success, to conclude that virtual elimination of inputs of persistent toxic substances has been achieved, that the injury has been eliminated, and that the ecosystem has been restored and is protected.

- Other particular issues associated with development and/or implementation of the virtual elimination strategy, such as remediation of contaminated sediment; sources of contaminants to the atmosphere; and waste storage, disposal, and destruction.

In its investigation of the components of the virtual elimination strategy and the application of the strategy to case examples, the Task Force also considered what tools to apply and opportunities to exploit, how and when, and by whom. Further, the Task Force considered and built on a range of relevant initiatives that have been or are being undertaken by others. The material comprising the remainder of this report is organized along these general lines. To the extent possible, the material represents the consensus of the Task Force members.

The initial advice presented in the Task Force's Interim Report (1) about the overall concept of the virtual elimination strategy and the specific components of the strategy served as the point of departure for the discussions in each of the following chapters. The Task Force also concurs with the concept of sustainable development, wherein a healthy economy and a healthy environment are inseparable and mutually achievable. Further, to undertake a virtual elimination initiative carries a degree of risk and uncertainty. However, these are usually accompanied by new opportunities for all stakeholders. These opportunities, in turn, foster cooperation and a sharing of responsibility for environmental protection. In its investigations and advice, the Task Force has endeavoured to recognize and build upon these to achieve the virtual elimination goal.

The conclusions and recommendations presented in Chapter 11 represent the Task Force's advice to the Commission about the development and implementation of the virtual elimination strategy.

2. TERMINOLOGY

In its charge to the Task Force, the Commission requested a definition of key terminology, including persistent toxic substance, zero discharge, and virtual elimination. The time spent defining these terms at the Task Force's public workshops, at the Commission's roundtables, in written comments to the Task Force, and among the Task Force membership is heartening: it indicates that commitments in the Agreement are being taken seriously.

The real challenge, however, is not to reach unanimous agreement on terms, but to achieve the goal of the Agreement: to restore and maintain ecosystem health. To accomplish this goal, the Task Force considered it necessary to include in its investigation the **presence** of persistent toxic substances in the ecosystem along with **inputs** to the ecosystem, as charged by the Commission (see Chapter 1).

For the purposes of this report, the definitions used are based on the language of the Agreement. However, in some cases, the Agreement language is not sufficient to develop a strategy to implement the policy of virtual elimination. Where appropriate, these definitions have been expanded.

2.1 PERSISTENT TOXIC SUBSTANCE, HALF-LIFE, AND BIOACCUMULATION

Article I of the Agreement defines toxic substance as one:

> "which can cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain, or in combination with other substances."

In Annex 12, persistent toxic substance (see sidebar) is defined as:

> "any toxic substances with a half-life in water of greater than eight weeks."

Half-life is defined as:

> "the time required for the concentration of a substance to diminish to one-half of its original value in a lake or water body."

A more extensive definition of persistent toxic substance is provided in the Commission's *Sixth Biennial Report* (3). The Commission recommended that:

> "The Parties expand the definition of a persistent toxic substance to encompass all toxic substances: with a half-life in any medium -- water, air, sediment, soil or biota -- of greater than eight weeks, as well as those toxic substances that bioaccumulate in the tissue of living organisms."

The terms *toxic substance* and *persistent toxic substance* are *not* interchangeable. While a persistent toxic substance always exhibits the characteristics of a toxic substance, the reverse is not the case. The virtual elimination strategy is driven by the characteristic of **persistence**.

The Task Force notes that the concept of half-life, as presented in the Agreement, has no accompanying scientific rationale. Half-life must consider all processes associated with the input to and removal of the substance from the ecosystem. Half-life is difficult or impossible to measure or calculate, and the value determined can vary depending, for instance, on where the substance enters the ecosystem and its propensity to move among media. In general, however, the longer that a substance remains in the environment, the longer and more accessible that substance is to living organisms.

The Task Force believes that half-life should be based on chemical, biochemical, and photochemical degradation processes and should not be based on such considerations as dilution processes.

The **bioaccumulation factor (BAF)** refers to the concentration of a chemical in the biota, received via all routes, divided by the dissolved concentration of that chemical in water. Substances with higher BAFs will accumulate in animals/humans to a higher level creating a greater potential for biological damage. Substances that bioaccumulate (including those that may combine with other chemicals and then bioaccumulate) should receive priority for virtual elimination, but other valid criteria must be considered in deciding on needed substance action (see Chapter 4).

Human activities have augmented the availability of metals, and the potential for them to cause injury to living organisms. Some metals (such as iron), though "persistent" according to the definition in Annex 12, should not be subject to the same stringent regulatory policies as other persistent toxic substances. However, other metals (notably mercury and lead), because of their potential to bioaccumulate after combining in the ecosystem with other substances (methylation), must be included in the definition of persistent toxic substance, as should a number of anthropogenic organometals and other metallic products.

2.2 ZERO DISCHARGE

As presented in Annex 12 of the Agreement, zero discharge is a "philosophy adopted for the control of inputs of persistent toxic substances" to guide regulatory strategies and ultimately to achieve virtual elimination. When applied to a chemical, the zero discharge philosophy implies adopting measures to eliminate any use or synthesis, or its existence anywhere in society. The Task Force concurs with this concept. Whereas the general intent of the phrase "zero discharge" is clear, its detailed implementation remains controversial.

In the Task Force's judgement the intent was to express the idea that it is necessary to eliminate inputs of persistent toxic substances, because the capacity of the ecosystem to assimilate these chemicals is small, or non-existent, and thus additional inputs will prolong impairment of ecosystem health.

For new substances that meet the definition of a persistent toxic substance (see Chapter 4), application of the zero discharge concept is straightforward: no synthesis or production -- no release. The Task Force also recognizes that minuscule quantities of persistent toxic substances already in the environment may escape capture or interception before entering the Great Lakes, even with the application of prevention, treatment, or control measures. Previous laws, regulations, and courts have also recognized the reality that application of the "zero discharge" philosophy cannot necessarily mean achievement of absolute zero. The Task Force believes this necessary interpretation should not impede progress towards the virtual elimination goal.

2.3 VIRTUAL ELIMINATION

The virtual elimination of inputs of persistent toxic substances is an obligation undertaken by the Parties in the 1978 Agreement and strengthened by the 1987 amendments to the Agreement. This commitment clearly intends that virtual elimination be one of the cornerstones to achieving an absence of injury and the Agreement goal of restoring and maintaining ecosystem health.

The Task Force offers the following observations and conclusions regarding virtual elimination. These are discussed further in Chapter 3.

- Current government programs controlling toxic substances, for the most part, fail to recognize any distinction between **toxic** and **persistent toxic** substances, as called for in Article II of the Agreement.

- Virtual elimination is an overall **strategy** that requires different approaches -- some preventive, some remedial -- to control or eliminate different inputs and *in situ* contamination.

- The virtual elimination strategy must apply to **all sources** -- point and nonpoint -- from **all media**.

- The virtual elimination strategy must apply to new potentially persistent toxic substances that may be created, as well as existing persistent toxic substances.

- The virtual elimination strategy also must apply to persistent toxic substances **already present** in the Great Lakes Basin Ecosystem. Once persistent toxic substances have been released into the ecosystem, it is not practical to completely remove them, especially from the open waters or the bottom sediments of the lakes, or from groundwater contaminated, for example, by leaking landfills. Therefore, the qualifier "virtual" is appropriate as applied to eliminating the presence of persistent toxic substances from the ecosystem.

- The virtual elimination strategy must **prevent** the deliberate input of any additional quantities of persistent toxic substances to the ecosystem. Given our technological capability to measure lower and lower concentrations of contaminants in the ecosystem, virtual elimination of existing persistent toxic substances may never be zero. Rather, the strategy challenges us to continuously strive to reduce the amount entering the environment, en route to fulfilling the Agreement's virtual elimination obligation.

- Because some persistent toxic substances already are present in the ecosystem, and because life in the Great Lakes Basin Ecosystem is vulnerable to contamination from persistent toxic substances, implementation of the virtual elimination strategy requires that the policy of zero discharge be applied to prevent further releases **from all sources** of persistent toxic substances.

THE VIRTUAL ELIMINATION STRATEGY

3. THE CONCEPTUAL APPROACH

The virtual elimination strategy should provide a comprehensive, multi-dimensional approach that addresses all problems associated with persistent toxic substances. It will affect each of us, and must guide industry as well as regulatory agencies by providing a road map to a Great Lakes no longer threatened by persistent toxic substances. If the strategy is to work, it must be fully understood and implemented both in the short and the long term. This chapter summarizes the basic concept of the strategy to virtually eliminate the input of persistent toxic substances to the Great Lakes Basin Ecosystem, specifically:

- A vision for the virtual elimination strategy.
- The need for the strategy.
- Limitations of current approaches toward persistent toxic substances.
- Evolution of approaches to dealing with persistent toxic substances.
- Principles of the virtual elimination strategy.
- Implementation of the strategy: action components and the decisionmaking process.
- Conclusions and recommendations.

Subsequent chapters examine the adequacy of available or required tools or processes to implement the strategy.

3.1 A VISION FOR THE VIRTUAL ELIMINATION STRATEGY

The virtual elimination strategy for persistent toxic substances must be guided by a vision. The Task Force's vision is ecosystem integrity, characterized by a clean and healthy Great Lakes Basin Ecosystem and by the absence of injury to living organisms and to society. The Task Force believes the virtual elimination strategy to achieve this vision must be compatible with and foster healthy, sustainable, economic activity.

3.2 THE NEED FOR THE VIRTUAL ELIMINATION STRATEGY

To understand why a strategy is needed that focuses specifically on persistent toxic substances, it is necessary to examine the limitations of our past approaches to these contaminants. Once we understand why we have not yet virtually eliminated persistent toxic substances, we can design a strategy with principles and components to help society achieve the virtual elimination goal.

A special strategy for the virtual elimination of persistent toxic substances is needed because these substances continue to damage ecosystem health, including subtle effects to the endocrine, immune, reproductive, and other sensitive biological systems. This is discussed more fully in Appendix D. This injury to living organisms continues to occur because of society's failure in the past -- and to a large extent even today -- to recognize fundamental differences between persistent toxic substances and other contaminants, especially their ability to resist degradation and, for some, to bioaccumulate in living organisms. A traditional assimilative capacity approach thus is not applicable to persistent toxic substances because even minute, undetectable quantities may build up over time to levels that cause biological injury.

3.3 LIMITATIONS OF CURRENT APPROACHES

While current practices to deal with persistent toxic substances have reduced the quantity released to the Great Lakes Basin Ecosystem, *a number of limitations preclude present practices from delivering virtual elimination.*

- *Limitation:* ***Proof of harm*** *must be established before responsive action is taken.* Years could be required to prove a conclusive link, by which time the damage has already occurred.
- *Limitation: Even after injury has been established, the traditional focus has been on* ***management and control*** *of releases, rather than prevention.* Thus, management practices that allow continued discharge of even the most damaging persistent toxic substances, although based on current regulatory objectives and available technology, may no longer be acceptable. Once a persistent toxic substance has been produced and used, it is impossible to completely control releases, including unintended releases. Recapturing every last molecule is impossible. Even when releases during the manufacturing process are controlled, releases can occur after the final product is discarded. Further, spills or accidental releases can occur during transportation and handling.

- *Limitation: With few exceptions, releases are controlled under current practices by* ***single-medium*** *laws and regulations designed to protect only air, land, or water.* As discussed in Chapter 5, persistent toxic substances enter the Great Lakes via many pathways and, once released, migrate among media, become widely dispersed in the ecosystem, and can end up in Great Lakes biota.

The traditional way of dealing with contaminants has assumed that the waters in the Great Lakes basin have an **assimilative capacity**. However, as noted above, this concept is inappropriate for persistent toxic substances. The Task Force believes that the current approach must change, because the following precepts do not necessarily hold for persistent toxic substances:

- *An ambient level exists below which residual risk is minimal.* Acceptable ambient levels are generally unknown for most persistent toxic substances. For some, the current scientific evidence indicates ambient levels so low as to be unmeasurable by the most sensitive analytical methods currently available.

- *If a "safe" ambient level exists, then protective water quality standards or numeric criteria can be established for persistent toxic substances.* To set a limit assumes that scientists are able to understand all possible effects of chemicals acting singly or in combination with one another on living organisms. Previous endeavours established limits for some persistent toxic substances which, in light of more recent information, were not protective (i.e. they were too high). In effect, for many persistent toxic substances, existing ambient environmental levels are already above the calculated or observed "no effect" level.

- *If a "safe" ambient level is determined and a water quality standard or criterion can be established, then it is possible to derive and allow for waste load allocations.* Allowing waste loads for persistent toxic substances adds to the exposure of and burden on the biota in the lakes.

However, as one component of the virtual elimination strategy, scientifically valid standards and criteria should be developed to serve as benchmarks to monitor progress in pollution cleanup and prevention.

In addition to limitations posed by current practices, concepts, and assumptions, technical and programmatic limitations also have prevented achievement of the virtual elimination goal. These include the failure to fully implement existing programs, enforce existing laws, and comply with existing policies, as well as a lack of funding and an adequate information base on loadings, sources, and available technologies. In Canada, for example, a National Pollutant Release Inventory is only now under development, while information from the U.S. Toxic Release Inventory underestimates total releases and lacks focus on persistent toxic substances.

Current estimates of the total number of chemicals in use range from 60,000 to 200,000, and the number continues to grow. Current practices cannot adequately screen existing chemicals nor screen all new chemicals (created either intentionally or as byproducts) for possible dangerous effects, especially chronic, sublethal effects on living organisms, and to determine which meet the definition of a persistent toxic substance. There also is no clear mandate to *eliminate* releases of those confirmed to be persistent toxic substances by any date. Moreover, present mechanisms are not adequate to eliminate the most dangerous substances from use, production, and disposal, even if it is determinated that they are too dangerous to be allowed to enter the ecosystem.

3.4 EVOLUTION OF APPROACHES

Historically, varied attempts have been made to cope with the problem of persistent toxic substances, usually commensurate with the level of understanding rather than the prevalence of the problem. The three phases in the evolution of attempts to deal with persistent toxic substances are summarized in Table 2 and discussed below.

Phase I: Controlling Releases of Persistent Toxic Substances

Initially and even today, the problems of water, air, and land pollution have been dealt with using treatment and control. The fundamental assumption governing the approach was the assimilative capacity concept, where methodologies were developed to find "acceptable" limits of pollutant releases. The goal is to reduce releases and eliminate any adverse effects. This approach reduced loadings to the environment. However, the levels of many persistent toxic substances remained at lower but still unacceptable levels through the 1980s and into the 1990s.

Phase II: Preventing the Use or Generation of Persistent Toxic Substances

Pollution control reactively addresses the problem once the substances have been used or generated. Prevention attempts to avoid use or generation in the first place through process change, product reformulation, and raw material substitution. In effect, prevention has required the focus to "move up the pipe" to examine the earliest source of the persistent toxic substance itself. The goal is clean production processes, closed loop recycling, and elimination of the use and generation of persistent toxic substances.

Table 2
The Evolution of Approaches to Persistent Toxic Substances

	I →	II →	III
	CONTROLLING RELEASES	**PREVENTING USE OR GENERATION**	**TOWARD SUSTAINABLE INDUSTRY AND PRODUCT/MATERIAL USE**
Focus	Release	Chemical use/generation	Materials
Policy	Control abatement technologies (Control technology change)	Use reduction Process/product changes (Process change)	Source/use profile (Use tree and life cycle concepts, industrial sector change)
Goal	Reductions in emissions levels Pollution control (acceptable levels)	Zero discharge/ sunsetting of targeted chemical Pollution prevention (clean production)	Zero production/use of certain elements/compounds Sustainable industry (Materials evaluation)

To date, neither government nor industry has been able to fully implement a pollution prevention approach. While some progress has been made, most programs tend to be media specific and fragmented compared to the need for comprehensive, integrated approaches (see Chapter 6). By one estimate (23), only 11% of United States companies filing reports under the Toxic Release Inventory were voluntarily using pollution prevention.

Phase III: Toward Sustainable Industry and Product/Material Use

In addition to implementing a prevention approach, inputs to industrial processes and societal practices need to be examined. This broader and much longer term approach involves an evaluation of the materials used in production processes and questioning the environmental appropriateness of those materials and the products.

This product/materials use notion raises many questions. In the present context the use of certain materials has the potential to result in the generation, use, or release of persistent toxic substances. Product/materials use makes us ask how and why we produce, use, transform, consume, and dispose of materials and products. This approach requires such questions as: Is it possible to eliminate the release of mercury when coal is burned to generate electricity?

The product/materials use approach not only asks what are sustainable and non-polluting production processes (as in Phase II), but also examines the benefits and negatives of entire industrial sectors, the building blocks of production, and various types of social activities. The goal of this approach is to move to sustainable societal activities and industries. This is where the development of a long-term virtual elimination strategy must start. Aids for understanding this framework include the use tree and the life cycle approach, discussed in more detail below.

3.5 PRINCIPLES OF THE VIRTUAL ELIMINATION STRATEGY

The unique properties of persistent toxic substances, coupled with the limitations of present practices and the evolution of strategic thinking, as described above, led the Task Force to articulate a set of principles that must guide a virtual elimination strategy focused on persistent toxic substances. The major principles that underlie the goals, objectives, and implementation of that strategy are **anticipation and prevention** and **remediation, treatment, and control**.

Anticipation and Prevention

Anticipation and prevention of pollution must be adopted for all substances that meet the criteria to be a persistent toxic substance. The virtual elimination strategy applies to all persistent toxic substances. All are presumed to be candidates for phaseout (sunsetting), particularly those with high bioaccumulation potential (see Chapter 4), unless data are available to

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In 1990, the President's Council on Environmental Quality concluded that:

> Thus it appears that the only chemicals to have declined significantly in the Great Lakes ecosystem are those whose production and use have been prohibited outright or severely restricted (24).

The production and use of the most harmful persistent toxic substances must be phased out in the near future following a strict negotiated timetable. The production and use of all other persistent toxic substances must be substantially reduced over the time period required to negotiate and arrange for their virtual elimination. The primary intent is to eliminate formation and/or use of persistent toxic substances, since this is the only way to virtually eliminate such substances from the ecosystem. Once created, it is impossible to recapture or totally eliminate every last molecule of a substance.

Remediation, Treatment, and Control

The virtual elimination strategy recognizes the clear, present need to **treat and control** all persistent toxic substances while they are being virtually eliminated from the Great Lakes Basin Ecosystem, and to **remediate** problems from past and present inputs. These efforts must address the legacy of industrial manufacturing, uses, and disposal over the past 150 years to the present, in concert with prevention and sunsetting mechanisms.

Other Principles

The virtual elimination strategy also adopts eight other principles. The strategy:

- Adopts a **precautionary principle** (see sidebar). Where there are threats of serious, cumulative, and/or irreversible damage, an incomplete understanding of the underlying science and an inability to arrive at a precise risk assessment value should not be used as a reason to postpone measures to prevent environmental degradation and to sustain the ecosystem resource.

- Addresses the **complete life cycle** of persistent toxic substances in society, including beneficial considerations, manufacture (deliberate or inadvertent), import, export, use, transport, disposal, destruction, and remediation.

- Applies to **all sources and pathways**.

- Applies to **all media** -- water, sediment, soil, air, and biota -- and the movement of contaminants from one to the other. The intent of the strategy is to eliminate a problem, not move it.

THE PRECAUTIONARY PRINCIPLE

"This (precautionary) principle was agreed to at the World Industry Conference on Environmental Management in 1984 and at the 1989 Paris summit of the seven richest industrial nations (the G7). It was strengthened in the 1990 U.N. Economic Commission for Europe meeting in Bergen: *In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*"

"Clearly, action is required [to bring about fundamental changes in our economic behaviour and our international relations]. But which actions, and when, given the huge uncertainties involved. This is the sort of issue that business copes with daily.... There are costs involved, but those are costs the rational are willing to bear and costs the responsible do not regret, even if things turn out not to have been as bad as they once seemed. We can hope for the best, but the 'precautionary principle' remains the best practice in business as well as in other aspects of life."

Source: Reference (25).

- Applies **globally**.
- Requires use of the principle of **reverse onus**, that is, the producer, user, or discharger of a substance bears the responsibility to demonstrate that neither the substance nor its degradation products or any byproducts are likely to pose a threat to the ecosystem.
- Involves **all stakeholders**, including a description of the relationship of business and industry to the people and wildlife that cohabit the region, and assumes maintenance of a robust economy that provides jobs and amenities to its residents (26).
- Applies the principle of **risk management** to select and evaluate proposed response options, once a substance has been identified as meeting the definition of a persistent toxic substance.

3.6 ACTION COMPONENTS FOR IMPLEMENTATION OF THE VIRTUAL ELIMINATION STRATEGY

The key components of the strategy to virtually eliminate persistent toxic substances from the Great Lakes Basin Ecosystem are: **elimination; adoption of a product/materials use policy; use reduction; and control, treatment, and remediation**. This strategy emphasizes the importance of prevention. However, application of the components will depend on the nature of the persistent toxic substance under consideration, as well as other factors such as its sources and uses. The components are described below. Clearly, the virtual elimination strategy will continue to evolve, as additional information and opportunities become available and as it builds on actions taken and successes achieved to date. These components of the virtual elimination strategy are intended to complement and enhance the programs and measures employed for the past two decades.

Elimination -- Sunsetting Persistent Toxic Substances

The Commission's *Sixth Biennial Report* (3) defined sunsetting as a "comprehensive process to restrict, phase out and eventually ban the manufacture, generation, use, transport, storage, discharge and disposal of a persistent toxic substance." Implicit in the concept is that uses of certain chemicals may be phased out using different timetables. For example, it may be possible to eliminate uses of mercury in batteries in the near future. However, eliminating all uses of mercury, including those for medicinal purposes, may occur over a longer time period.

The overriding goal is to eliminate the formation and use and, thus, the release of all persistent toxic substances. However, that is not possible in the short term for all persistent toxic substances. In the interim, to lead towards the virtual elimination goal, a preventative approach should be applied to all persistent toxic substances.

Immediate bans and phaseouts according to a strict timetable are required for a "short list" of selected substances subject to the virtual elimination strategy. As a matter of urgency and to address the immediate hazards of those persistent toxic substances which have, and continue to cause environmental damage, action should be taken to ban at once, or phase out in the very near future, all production, manufacture, import, export, use, release, transport, and disposal of the 11 Critical Pollutants (Table 1). All are known to cause detrimental effects on living organisms and continue to exist in the ecosystem at unacceptable levels. This is discussed further in Chapter 4.

To determine priorities for phasing out additional persistent toxic substances, government, in consultation with stakeholders, must devise comprehensive criteria and decisionmaking procedures to evaluate all persistent toxic substances not on this short list, following a stringent timeline. These criteria must be applied to all persistent toxic substances, whether they are created intentionally or as byproducts. "Sunrise" criteria are also needed to evaluate new chemicals, including chemicals that may be created as alternatives to those that are slated to be phased out. These criteria are described in Chapter 4, and decisionmaking procedures are suggested later in this chapter.

Adoption of a Product/Materials Use Policy -- The Use Tree and Life Cycle Approaches

Government and industry, in consultation with stakeholders, must evaluate classes of chemicals and chemical families through use tree analysis, to determine whether and how particular uses should be phased out. As depicted in Table 2, government and industry historically have tried to control releases, but that has not been enough. The importance of "moving up the pipe" is now recognized as a management option, and both are now shifting to prevention and other related measures to avoid the use and generation of persistent toxic substances. The next step is to question some of the raw materials used by industry and society, as well as societal practices.

One means for doing this is the use tree concept. A use tree outlines the end uses and products of chemicals, and then traces those to identify the families of chemicals back to the base element, compound, or mixture. Such a methodology helps to clarify the sources or origins of a persistent toxic substance.

Use tree analysis has been used by industry and engineers for some time; what is different is using it in terms of environmental policy and/or regulations to determine the most appropriate point of intervention. Some substances can be dealt with at the "release" stage, at least in the interim. Some persistent toxic substances, however, can and should be dealt with at the root level on the use tree.

A use tree is only a tool. It does not indicate whether something should be phased out, nor does it prescribe how to do so in terms of regulatory and non-regulatory initiatives. The use tree simply enables one to ask the fundamental question: What is the source of a persistent toxic substance?

In terms of policy and regulations, a use tree analysis allows the following kinds of questions to be asked:

- Where should society intervene to deal with a substance or class of substances: At the release level? At the point of production of precursor chemicals? Or at some intermediate point?

- How do we evaluate where and how to intervene? What is the relationship among environmental, social, and economic considerations? What research is needed to shed light on these questions?

- For new materials, how do we respond to the above questions?

For example, the root of the mercury tree may be mining. One option would be to phase out certain mining sectors, while other options would be to reduce the use of certain applications or uses in certain circumstances. Thus, the use tree provides a framework that enables society to consider the question: Where do we intervene to most appropriately prevent further problems?

Use Reduction

Sunsetting for persistent toxic substances will take time. Therefore, government, in consultation with stakeholders, must implement a preventative strategy for all persistent toxic substances, using the concept of "sustainable manufacturing." This term incorporates pollution prevention, use reduction, and product life cycle analysis. Some key elements of use reduction and elimination programs are:

- Progressively reducing releases of persistent toxic substances, achieved through cooperative, voluntary approaches.

- Making information publicly available on current chemical uses and inventories, as well as facilities' current plans and progress for reducing uses and releases.

- Issuance of permits or approvals for operation and contaminant release, only if use reduction plans for persistent toxic substances have been submitted.

- Provision of technical assistance, especially to smaller facilities, to help determine the most appropriate use reduction method or technology.

- Societal provision for worker retraining and other technical assistance for those whose jobs are lost as a result of the phasing out of a chemical.

Control, Treatment, and Remediation

Elimination, product/materials use policy, and use reduction will not occur overnight for all identified persistent toxic substances. Therefore, treatment and control actions must be applied as intermediate or interim measures, and possibly as long-term measures where necessary, en route to achieving virtual elimination. Treatment and control should focus on intercepting or capturing the persistent toxic substance once it has been produced or used, but before it can enter the ecosystem. Technology can be applied to treat and control point source discharges, air emissions, and nonpoint sources.

Remediation focuses on cleanup of contaminants already in the ecosystem. Technology is an essential tool, but our ability to remove contaminants is limited once they enter the ecosystem.

The full extent of the environmental problems attributable to past releases which now reside in contaminated sediment, leaking landfills, or other uncontrolled sites is unknown. In the United States, through the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), an inventory of locations of inputs is underway and has been completed in some states. In Canada, the Contaminated Sites Program, under the auspices of the Canadian Council of Ministers of the Environment, is involved in a similar effort. However, releases of contaminants have not been quantified at all sites; estimates are available only in limited cases.

As discussed in Appendix D, the costs of cleanup are only now beginning to be reckoned. To remove or contain contaminants, to operate and maintain facilities, and to monitor contamination is estimated to cost billions of dollars, with time frames for remediation of 30 years and more. This is not unreasonable, given the experience with RCRA and CERCLA.

A long-range plan is required to systematically focus on sediment, landfills, and other unregulated sources, to monitor and assess the varying degrees of contamination from these sources, and to develop plans to address first the sites that are the most likely sources of inputs to the ecosystem. Included in a site-by-site assessment would be an analysis of whether, given best available technology, the contamination would be better left in place, with no further action taken other than monitoring.

A remedial management program is needed for contaminated sediment, even with a long-range plan. Particular consideration should be given to the environmental effects from dredging. This means employing a multi-media approach, with best available technology for the management, control, and disposal of dredged spoils.

Remedial Action Plans represent a useful mechanism to identify cleanup needed and to move toward the virtual elimination goal; in fact, Annex 2 of the amended Agreement recognizes the connection. Similarly, lakewide management plans, point source impact zones, and watershed management plans -- also Agreement requirements -- offer opportunities to apply the strategy to virtually eliminate inputs of specific pollutants.

Programs must provide economic incentives to drive improvements and the development of better and less expensive technologies for remediation, cleanup, and control. Persistent toxic substances continue to cause injury to the economy and society in the form of environmental debt, attributable to 150 years of industry and manufacturing in the Great Lakes region. Government and industry, in consultation with stakeholders, must adopt and maintain programs targeted toward remediation or control of inputs of past and present contamination, while continuing to recognize that prevention must be paramount.

Recognizing that it will not be possible to clean up and control all inputs, all at one time, the virtual elimination strategy must include a comprehensive approach to remediation and control. This must include:

- Information to compile inventories of all releases from leaking landfills and other uncontrolled sources.
- Identification of the most serious contamination sources targeted for removal and destruction, with a program to monitor and assess other areas of contamination, in order to target additional areas for either remediation or control.
- Environmentally sound strategies for managing sediment removal as needed for navigation on the Great Lakes, e.g. confined disposal, landfills, and control of releases during dredging and thereafter in sediment disposal or destruction.
- Application of best available technologies for groundwater contamination, sediment removal, remediation, and control.

3.7 THE DECISIONMAKING PROCESS

Important considerations in the implementation of the virtual elimination strategy include:

- Having a decisionmaking framework within which to operate.
- Having the tools, including legislation, technology, economic instruments, and consultation mechanisms.
- Having a strong mandate.

The decisionmaking framework presented here provides a coherent means to examine the nature and dimensions of the problems created by the need to virtually eliminate persistent toxic substances. The framework provides for plausible short- to long-term implementation responses, as well as for input from all sectors of society (government, industry, labour, public). It draws on a variety of disciplines and employs a wide range of tools in order to anticipate the consequences of the decisions that are ultimately reached.

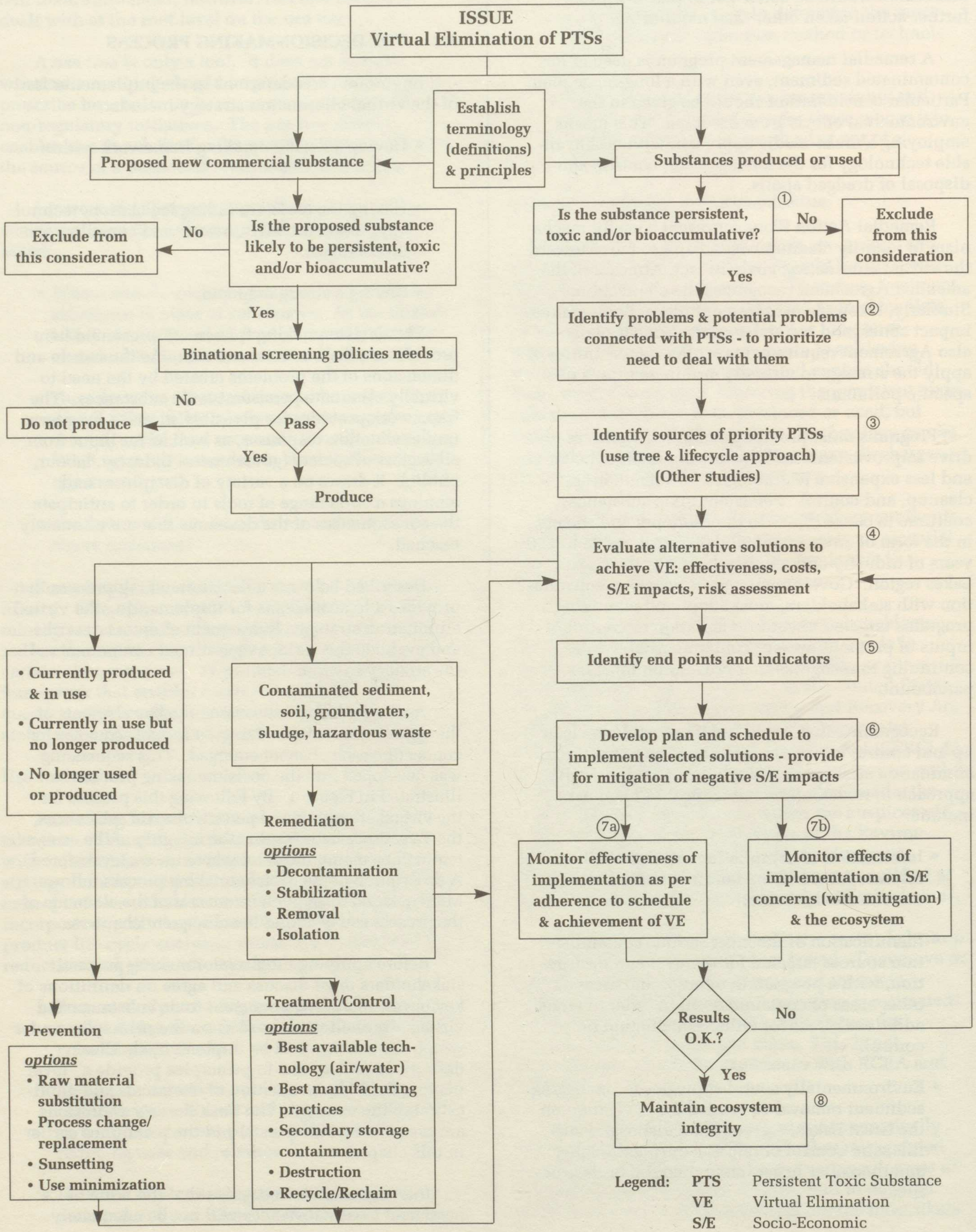
Described below is a decisionmaking process that provides a logical means for implementing the virtual elimination strategy. Subsequent chapters describe and evaluate the various operational components of the strategy in more detail.

As the Task Force discussed the key elements of the virtual elimination strategy, a logical sequence for connecting each element emerged. This sequencing was developed into the decisionmaking process illustrated in Figure 1. By following this process for the virtual elimination of persistent toxic substances, the Task Force believes that the integrity of the ecosystem will be maintained and where necessary restored. A description of the decisionmaking process follows. More detailed discussion on several of the elements of the process can be found in subsequent chapters.

Before applying the decisionmaking process, stakeholders must discuss and agree on definitions of key terms, including persistent toxic substance and virtual elimination, as well as on the principles under which the strategy will be implemented. Clear definitions and agreed-to principles provide a "level playing field" for evaluation of chemicals and application of the strategy. The Task Force's definitions are presented in Chapter 2, and the principles earlier in this chapter.

It is important to recognize that the issue of persistent toxic substances will not be adequately

Figure 1
Decisionmaking Process for Virtual Elimination of Persistent Toxic Substances from the Great Lakes



addressed by dealing solely with substances currently in use or in the ecosystem. Provisions are made in this strategy to deal with proposed substances. Figure 1 illustrates the two pathways that a decisionmaker will follow, depending on whether a substance is currently in commercial use or whether there is a new substance under consideration for commercialization. The decisionmaker at that step can be either in government or business.

Screening Proposed New Commercial Substances

The screening process and the criteria should be bilateral and include manufactured (deliberate and inadvertent) and imported chemicals. Both Canada and the United States have set up procedures to establish if a chemical should be approved for manufacture in commercial quantities. In Canada, the requirements are described in the Canadian Environmental Protection Act (CEPA). In the United States, the Toxic Substances Control Act (TSCA) requires the submission of a premanufacturing notification (PMN) to the U.S. Environmental Protection Agency (EPA). The contents of a PMN should allow U.S. EPA to assess the appropriateness of the application. Since this strategy deals specifically with persistent toxic substances, the first decision is to assess if the substance under consideration fulfils the criteria to be defined a persistent toxic substance. See Chapter 4 for more details on selection criteria. Knowledge of the substance's composition or chemical structure, along with the physical and chemical properties, will guide decisionmaking. A substance that is unlikely to meet the definition of a persistent toxic substance can be excluded from further consideration. The adequacy of CEPA and TSCA as screening mechanisms should be evaluated to ensure they allow screening and also are consistent with the principles of the virtual elimination strategy.

Screening Existing Substances

The process outlined below is for substances currently being manufactured (deliberate and inadvertent) and in use, still in use though no longer produced in commercial quantities, or no longer produced or used.

- **Element 1. Apply selection criteria**. As was established for a new substance, the first element in the process to deal with an existing substance is to assess whether it fulfils the criteria to be defined a persistent toxic substance and is therefore to be dealt with under the strategy (see Chapter 4 for more details on selection criteria and the screening process). Knowledge of the substance's composition or chemical structure, along with the physical and chemical properties, will guide decisionmaking. A substance that does not meet the definition of a persistent toxic substance can be excluded from further consideration from this flow diagram, but is referred to the existing regulatory regime for toxic substances for appropriate consideration and action.

- **Element 2 - Prioritize persistent toxic substances of concern**. Since it is unlikely that all issues involving persistent toxic substances can be dealt with at one time, it is necessary to decide which should be dealt with first. At this point, it may be decided to deal specifically with one substance or a set of substances.

- **Element 3 - Identify sources and uses of the substance(s)**. The intent is to establish where the substance is entering the environment. Since human activities, industrial processes, and industrial sectors generate the substance or class of substances, a use tree and life cycle approach is appropriate for this undertaking.

- **Element 4 - Evaluate alternative solutions for achieving virtual elimination and select preferred options.**

Figure 1 provides a breakout of Element 4 (see also sidebar on the following page). Persistent toxic substances fall into four broad areas: those currently produced (deliberately or inadvertently) and in use; currently in use but no longer produced; no longer used or produced; and those resident as contaminants in sediment, soil, groundwater, sludge, and sites that have received hazardous waste. As discussed earlier, the actions to be taken fall into the categories of prevention, treatment, control, and remediation. Figure 1 lists some options available (see also sidebar on the following page).

There is a difference of opinion among Task Force members as to the priority for action. For some, only prevention options, which lead directly to elimination of persistent toxic substance formation in the first place, are acceptable. However, preventative solutions may have a relatively long time frame. Other options, such as treatment and control, would therefore be required to achieve a more rapid and positive initial benefit. In reality, all options must be considered and implemented concurrently and as appropriate, to **mutually** contribute to achieving the virtual elimination goal.

A great many factors must be considered in selecting and implementing solutions, for instance, significance of the risks to health and the environment, availability of technology to achieve the desired end point, social and economic impacts, and consensus among stakeholders. All proposed solutions must be subjected to risk assessment and socioeconomic impact assessment, in order to prepare timetables and, where required, mitigation measures.

- **Element 5 - Identify endpoints and indicators.** In this element, endpoint goals for the selected

ALTERNATIVE SOLUTIONS TO ACHIEVE VIRTUAL ELIMINATION

(See Figure 1, Element 4)

For persistent toxic substances **currently produced and in use**, the focus is on the manufacturing process used. Available solutions fall broadly into the area of prevention, for example, raw material substitution, process change or replacement, material recycling or reclamation, and use minimization.

For persistent toxic substances **in use but no longer produced**, the focus is on substitute substances or systems.

For persistent toxic substances **no longer used or produced**, treatment and control actions will reduce contaminant release toward the desired virtual elimination endpoint, for example, best available technology and best manufacturing practices. For stored or disposed substances, secondary containment may be advisable. Destruction, reclamation, and recycling may be appropriate for substances in storage, where the result would be a reduced loading to the environment.

Contaminated sediment, soil, groundwater, sludge, and hazardous waste sites involve persistent toxic substances **already in the ecosystem**. The basis for action must consider whether it is preferable to remove or isolate the substance, and which solution produces the minimum overall impact on the environment. Spill containment and control are ways to prevent further ecosystem contamination and thus also contribute to preventive action.

solutions are adopted, and indicators of movement toward these goals are specified. See Chapter 10 for more discussion of indicators.

- **Element 6 - Implement preferred solution(s).** In this element, the preferred solution(s) that lead to reduction and ultimately elimination of inputs of persistent toxic substances are implemented following an agreed-to time line. Provisions are needed to mitigate possible negative social and economic impacts resulting from actions taken.

Two monitoring streams follow Element 6:

- **Element 7A - Monitor effectiveness of implementation, as per adherence to schedule and achievement of virtual elimination.** Once the solution has been implemented, monitoring must be maintained to ensure that the solution is being implemented as required and is leading to virtual elimination of the targeted persistent toxic substance or set of substances.

- **Element 7B - Monitor effects of implementation on socio-economic concerns and the ecosystem.** The implemented solution may have effects on society, the economy, or the ecosystem that were not predicted. Monitoring is required to ensure that such concerns do not develop. If they do, mitigating actions need to be taken.

Elements 7A and 7B lead to the question: Have the implemented solution(s) led to the desired end points of the indicators? If not, further solutions need to be addressed by returning to Element 4. If yes, the issue is resolved, and one proceeds to Element 8.

- **Element 8 - Maintain ecosystem integrity.** Monitor ecosystem integrity, addressing the indicators discussed in Chapter 10.

3.8 CONCLUSIONS AND RECOMMENDATIONS

The Virtual Elimination Task Force articulates a simple vision regarding persistent toxic substances: ecosystem integrity, characterized by a clean and healthy Great Lakes Basin Ecosystem and by the absence of injury to living organisms and to society. The Task Force has considered what must be done to achieve this vision.

The Task Force concludes that many principles of past pollution-response practices are not appropriate when dealing with persistent toxic substances. The Task Force also observed an evolution in thinking, from control to prevention, toward sustainable industry and product/material use. Consequently, the Task Force has articulated the essential principles and components of a strategy to virtually eliminate the input of persistent toxic substances to the ecosystem, and has also developed a decisionmaking process to implement that strategy. The Task Force firmly believes that implementation of the strategy will achieve the Task Force's vision and the Agreement's virtual elimination goal.

Therefore, the Virtual Elimination Task Force recommends that:

1. **The Commission and the Parties adopt the vision: ecosystem integrity, characterized by a clean and healthy Great Lakes Basin Ecosystem and by the absence of injury to living organisms and to society.**

2. **The Commission and the Parties immediately adopt the Task Force's strategy to virtually eliminate the input of persistent toxic substances to the ecosystem, including its fundamental principles and components and the decisionmaking process to implement the strategy.**

EVALUATION OF STRATEGY COMPONENTS

In Chapter 3, the Task Force laid out the concept of a virtual elimination strategy. In the following chapters, the Task Force describes, examines, and evaluates the components of the strategy. An intimate understanding of each component is essential if the strategy is to be applied successfully. The chapters that follow:

- Describe the criteria and procedure to be used to determine which substances are persistent and toxic and should, therefore, be subject to the virtual elimination strategy.

- Discuss sources and uses of selected persistent toxic substances. This allows identification of intervention points to eliminate and prevent inputs to the ecosystem and to respond to contaminants already in the ecosystem.

- Examine how virtual elimination can be achieved. The arsenal of tools and opportunities consists of: legislation, regulations, and associated programs; technology; economic instruments; educational and consultation opportunities; plus other tangible and intangible considerations such as multi-stakeholder initiatives and non-regulatory factors.

- Identify indicators that measure progress toward the virtual elimination goal and achievement of the absence of injury.

Each of the tools and opportunities noted above is necessary but, by itself, not sufficient to achieve virtual elimination. Their relative utility in a virtual elimination strategy depends on several factors and circumstances associated with the persistent toxic substance under consideration, such as its uses, means of generation, and sources to and location in the ecosystem.

Although these tools and opportunities are interrelated, they have been separated into four component chapters for the purposes of evaluation. As part of its evaluation, the Task Force has considered what has worked and why, as well as what has not and why not. More specifically, the Task Force has considered what specific tools and opportunities are available, their contribution to past successes, limitations to their application and use to deliver virtual elimination, the extent to which these barriers can be overcome, the extent of additional ecosystem restoration and protection possible through their use, changes required to improve their effectiveness (e.g. new directions, orientation, and philosophy), how to effect changes in tools and opportunities, and impact on setting timetables and schedules. This evaluation of how virtual elimination can be achieved has direct application to the case examples presented in Appendices A and B.

4. SELECTION OF CHEMICAL SUBSTANCES

4.1 INTRODUCTION

The goal of the virtual elimination strategy is to deal with all persistent toxic substances. These chemicals must be identified from the more than 10 million already known to exist. Each substance possesses different chemical, physical and toxicological properties. In terms of potential risk, each has a different pattern.

The criteria that define persistent toxic substances, and the actions taken to implement virtual elimination, involve a number of levels of investigation. The usual approach is to look at each substance separately and in isolation, distinct from production and use processes, waste disposal activities, source and loading considerations, environmental pathways, and transformation and fate which, together, comprise the substance's life cycle. This chemical-by-chemical approach is illustrated in Figure 2.

When individual substances are considered in isolation, the potential harm they possess can be viewed as falling on a one-dimensional continuum from "not harmful" to "very harmful." The selection process, however, cannot be adequately represented by a one-dimensional line. Rather, the approach must include consideration of a multi-dimensional continuum where the nature of chemical synthesis and the various aspects of the chemical's life cycle, as noted above, are considered. It may be appropriate to consider classes or groups of chemicals, as well as synergistic effects among chemicals.

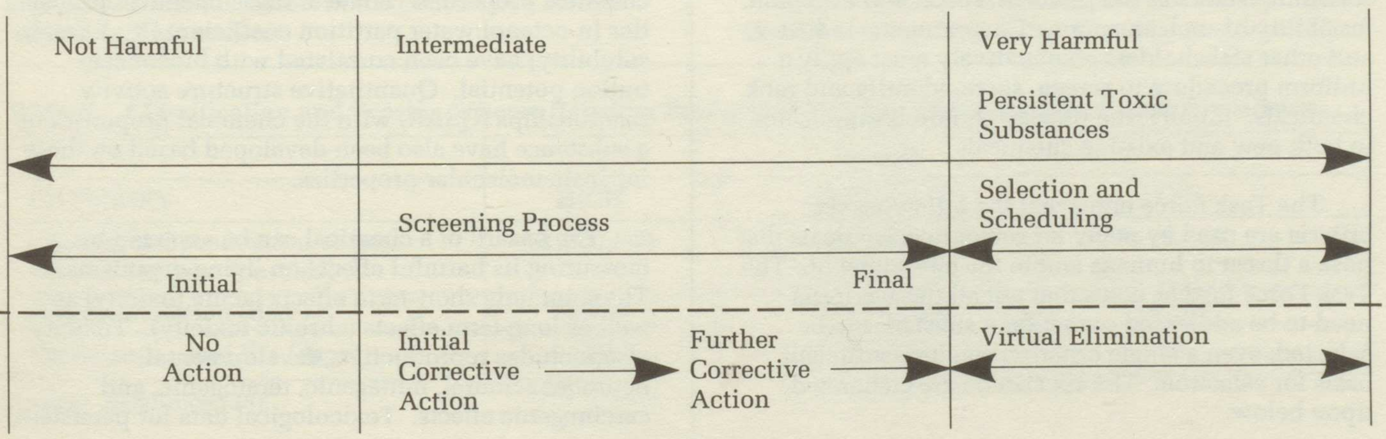
The nature and extent of the response or action required, as part of a virtual elimination strategy, depends on the nature and the extent of the threat that a chemical (or group of chemicals) poses. Only those that meet the criteria to be classified as persistent toxic substances will be subject to virtual elimination. However, once identified, it is unlikely that all persistent toxic substances can be dealt with at one time. Therefore, it will be necessary to select them for phaseout.

4.2 SELECTION PROCESS

The identification of persistent toxic substances and their selection for phaseout, as depicted below, may consist of:

- Initial screening: to sort chemicals and identify **potential** persistent toxic substances, using selected scientific criteria that describe the extent of injury/threat they pose, and hence the extent of response required.
- Subsequent screening: to identify those chemicals that meet the definition of persistent toxic substance, again using scientific criteria.
- Selection for phaseout: to stratify confirmed persistent toxic substances and establish specific timetables for phaseout, factoring in other considerations. These other considerations include inherent properties or characteristics that allow grouping or sorting the chemicals, as well as consideration of specific human activities and processes (industrial and otherwise) that generate or use the substance and related or similar substances, either deliberately or inadvertently.

Figure 2 The Selection Process



The screening process is applicable for existing as well as new chemicals. Those chemicals that are not classified as persistent toxic substances but still pose a threat should still be subject to management action.

4.3 THE SELECTION CRITERIA: QUALITATIVE CONSIDERATIONS

Numerous detailed assessment procedures developed in Canada, the United States and elsewhere worldwide identify those chemicals that pose a threat and rank them according to the nature and extent of that threat. Many lists of substances of concern have been produced. Examples relevant to the Great Lakes include the Michigan Critical Materials Register; the U.S. Environmental Protection Agency's (EPA) Priority Pollutant List; the 1986 Working List of [362] Chemicals in the Great Lakes Basin, published as an annex to the *1987 Report of the Great Lakes Water Quality Board* (27); the Ontario Effluent Monitoring Priority Pollutants List; the Wisconsin Department of Natural Resources Acute Toxicity Criteria for Substances; and the three lists developed by the United States and Canada to meet the requirements of Annex 1 of the amended Agreement.

A Task Force examination of these and other selected assessment procedures and lists point to several similarities and differences (28). The Task Force observes a diversity of opinions used in the development of these lists, including rationale for selection, relative importance, policy implications, and application to new and existing substances. Which criteria, their relative importance (e.g. do they carry equal weight), and the critical or threshold values associated with these criteria are key factors in determining which substances are or are not selected, and ranking their importance for subsequent action.

The product of the selection process, which is based largely on scientific information, is a list of substances that fulfils the definition of persistent toxic substance and must, therefore, be subject to virtual elimination. Following the selection process, further analysis of the chemicals to be subject to virtual elimination should then consider such non-scientific factors as the political, social and economic feasibility of such an action. Governments, industry, and other stakeholders cooperatively must apply a uniform procedure to screen, score, identify and rank chemicals. Finally, the process should be applicable to both new and existing chemicals.

The Task Force notes that the following six criteria are used by many for screening chemicals that pose a threat to humans and to the environment. The Task Force further notes that not all these criteria need to be addressed or met for a substance to be selected; even a single criterion can be a sufficient basis for selection. The six criteria are elaborated upon below.

- Amounts produced/used/released
- Presence/behaviour in ecosystem including persistence, bioaccumulation, extent of distribution
- Chemical properties
- Toxicological properties
- Exposure potential
- Threats to ecosystem integrity or evidence of cause-effect linkage between persistent toxic substances and biological injury

The release of chemicals through production (deliberate and inadvertent), manufacturing processes, use, transport, accidents, and disposal may result in contamination of the environment and pose a threat to biota and humans. U.S. EPA (29) has proposed that substantial production in commerce refers to chemicals produced in quantities of 1 million pounds (454,000 kg), and that substantial release refers to chemicals released to the environment in quantities greater than 1 million pounds/year. U.S. EPA states that 37% of the listed chemicals have releases over 1 million pounds. Chemicals with high production >1,000,000 pounds should be considered in the selection processes.

The Task Force believes that important criteria to use to determine initially which substances are of concern are **persistence** (expressed in half-life) and the tendency for a substance to be taken up by and accumulate in the tissues of biota and humans (**bioaccumulation**). The tendency of a chemical to concentrate in tissues should be generally measured by the bioaccumulation factor (BAF) rather than the bioconcentration factor (BCF), since BAF accounts for accumulation through the food chain. BAF can be measured in the laboratory but, preferably, in the field. Half-life and bioaccumulation are defined and discussed in Chapter 2.

The chemical properties of a substance usually dictate its fate and transport in the environment. For example, a low water solubility will increase its tendency to bind to sediments and bioconcentrate or bioaccumulate in biological tissues. Several models have been developed (41,42) to predict the behaviour of chemicals in specific environments based on their chemical properties. Some of these chemical properties (n-octanol:water partition coefficient (K_{ow}), water solubility) have been correlated with bioconcentration potential. Quantitative structure activity relationships (QSAR) with the chemical properties of a substance have also been developed based on these intrinsic molecular properties.

The hazard of a chemical can be assessed by measuring its harmful effects on living organisms. These include short-term effects (acute toxicity) as well as long-term effects (chronic toxicity). Toxicity also includes reproductive, developmental, neurobehavioural, mutagenic, teratogenic, and carcinogenic effects. Toxicological data for persistent toxic substances are limited, but toxic endpoints can also be predicted with QSAR models. Injury to biota also includes a wide range of harmful effects which are more insidious than previously thought. These effects include population declines, reproductive effects, eggshell thinning, "wasting," gross defects, tumours, immune suppressions, generational effects, and behavioural changes. Effects on living organisms are discussed more fully in Appendix D.

Exposure potential is assessed in categories that include the bioaccumulation potential, persistence, and amount of chemical that is produced and/or released to the environment. Exposure assessment models have been used to estimate exposure potentials of chemicals in the environment (41,42). This is discussed in Chapter 5.

Ecosystem integrity comprises the Task Force's guiding vision for the virtual elimination strategy, presented in Chapter 3. A linkage of the injury to selected species in the Great Lakes, posing a threat to the integrity of the ecosystem, can be attributed to their exposure to specific persistent toxic substances (see Table D-3). A wealth of evidence has been collected (11,33-37) which suggests that specific persistent toxic substances have a wide range of long-term impacts and varied effects on certain fish and wildlife. While fish and wildlife can be regarded as indicators of a stressed Great Lakes, there may also be a link between persistent toxic substances and human health problems. The cause-effect link between persistent toxic substances and injury to living organisms is discussed in Appendix D.

4.4 THE SELECTION CRITERIA: QUANTITATIVE CONSIDERATIONS

The Task Force recognizes limitations to its ability to assign quantitative values for the selection or prioritization of chemicals for virtual elimination. Nonetheless, based on the survey conducted of selection criteria used to assemble toxic chemical lists (28) and a report on identifying chemicals for sunsetting (38), some quantitative aspects of the parameters considered in the previous section can be highlighted and discussed in the context of a screening and scoring system.

Many schemes identify potential risk and candidate substances for evaluation through bioaccumulation, persistence, and other scientifically based criteria, then evaluate exposure hazard (risk assessment) by considering the amount of substance produced and released. Table 3 presents a classification and scoring scheme for bioaccumulation, persistence in a critical medium, and release and production volume. The release and production volume values are used by U.S. EPA. The Task Force considers these insufficient, because they do not consider inadvertently produced persistent toxic substances, contaminants already in the ecosystem, nor the locale of production and use.

The Task Force's examination generally suggests that BAF scoring is relatively arbitrary. Some indicate that chemicals that pose a hazard to humans and to aquatic and terrestrial organisms generally have a BAF >1,000. A number of scoring procedures indicate that a BAF >5,000 is of high concern.

The Task Force believes the time scale for persistence is adequate, as given in Annex 12 of the Agreement, for a chemical to exhibit adverse effects based on acute and chronic exposures, depending on the organism. Based on Foran's survey (38), persistence of seven days is considered a low score and >56 days (eight weeks) is of high concern.

Toxicity is assessed in terms of adverse effects to aquatic biota for most of the lifetime of an organism (chronic) as opposed to much less than the lifetime of an organism (acute). It includes toxicity to terrestrial, avian, non-mammalian and mammalian species on both acute and chronic exposures. Toxicity data, however, are quite limited. The inability of toxicology to identify all persistent toxic substances can be overcome by making predictions through structure-activity relationships (QSAR), using available data for groups or clusters of related compounds. Substances with a substantial data base (such as the 11 Critical Pollutants presented in Table 1) can be used as a starting point to make predictions for other virtual elimination candidate substances, for which only limited information exists.

The Task Force recognizes that the concept that "the dose makes the poison" must be considered in

Table 3 Classification and Scoring Scheme Based on Production Volume, Bioaccumulation, and Persistence

	SCORE		
CATEGORY	HIGH	MODERATE	LOW
Commercial production or use volume per year (pounds)	>1,000,000	100,000 - 1,000,000	<100,000
Bioaccumulation (BAF)	>5,000	1,000 - 5,000	<1,000
Persistence - half-life (days)	>56	7-56	<7

Source: Reference (38).

assigning risk. While it is true that the toxic effect of a chemical is dose related, there are situations where the length and the time of exposure are as important. The harmful dose level is also related to the toxic activity of the substance and the ability of the substance to penetrate to the target organ. Also, real-world exposures are seldom to single substances, but usually to complex mixtures of chemicals whose composition varies with time. Table 4 and the following summarize values assigned for acute and chronic toxicity to living organisms:

- Acute toxicity to aquatic organisms. Together with quantitative information on dose, assigned values on toxicity (risk) cover a broad spectrum.

- Chronic toxicity to aquatic organisms. The No-Observable-Adverse-Effect-Concentration (NOAEC) is based on a common endpoint. This desired measure of chronic toxicity is expressed as a concentration to which a population of the organism is exposed for most of its lifetime and below which no measurable adverse effect is observed.

- The LD_{50} is a measure of acute toxicity to terrestrial, avian and non-mammalian species. LD_{50} is the dose that is lethal to, or effectively immobilizes 50% of a test population within a specified time period.

- The NOAEC is used for chronic exposures of terrestrial, avian and non-mammalian species to persistent toxic substances.

- LD_{50} is used as the measurement of acute lethal mammalian toxicity.

The classification and scoring systems presented in Tables 3 and 4 show differences and similarities among agencies conducting these assessments. Nevertheless, by whatever procedure and for whatever purpose, the important point is that a number of chemicals have been identified as posing a threat to the ecosystem and thus action is required. As noted in Appendix D, certain chemicals are responsible for specific effects in birds, fish, and other living creatures.

For the initial screening to sort and identify potential persistent toxic substances, the Task Force suggests that the following criteria and values be used: BAF >1,000; persistence >7 days; and chronic toxicity to aquatic organisms <1 µg/L. A score that exceeds the indicated value for any one of the criteria would identify a chemical as a potential persistent toxic substance and would mandate initial corrective action and further consideration, as well as establishment of timetables.

Application of more stringent values in subsequent screening would identify those chemicals that meet the definition of persistent toxic substance and which, according to the Agreement, should be virtually eliminated. The Task Force suggests that, to identify those requiring immediate action, the following criteria and values should be considered: BAF >5,000; persistence >56 days; chronic toxicity to aquatic organisms <0.1 µg/L; and demonstrated specific causality and/or injury to biota. For chemicals not yet introduced into use, a strong indication (as determined, for example, through QSAR) of potential injury to biota should be applied as a "sunrise" criterion. A score that exceeds the indicated value for any one of the first three criteria, in combination with demonstrated specific injury to biota, would classify the chemical as a persistent toxic substance and a candidate for phaseout.

In scheduling a persistent toxic substance for phaseout, the utility of the use tree and life cycle approach (discussed in Chapter 3) must be considered. The leaves on the outermost branches of the use tree represent persistent toxic substances in the environment. Intermediate branches can represent intermediate chemicals and products, and the root the basic precursor chemicals or process. By starting with the leaves (the persistent toxic substances) on the use tree and working toward the tree's root, one can identify the human activities responsible for the substance's formation, as well as the relations between them. The selection strategy presented in this chapter therefore focuses on not just the chemicals but also on human activities.

Different phaseout dates can be established for different uses. The timing is also dependent on several factors, including the availability of alternatives; the ecological, economic, and societal implications of phaseout and the alternatives; as well as the available legal instruments.

The Task Force has given particular consideration to the 11 Critical Pollutants identified by the Commission's Water Quality Board in 1985 (see Table 1). All 11 substances are persistent and cause such serious injury to living organisms that any entry into, or presence in the ecosystem is unacceptable. The Task Force notes that the 11 Critical Pollutants have, in effect, already been subjected to evaluation. It is interesting to note that the 11 appear on most, if not all the toxic chemical lists surveyed (28). All are subject to regulation, and actions taken over the past 20 years have significantly reduced ecosystem concentrations. However, levels in the ecosystem continue to be elevated. Thus, the 11 Critical Pollutants are ideal candidates to determine *why* environmental levels remain elevated, and whether additional actions can be taken to virtually eliminate inputs. The Task Force considers all 11 to be persistent toxic substances and, through application of the virtual elimination strategy and its decisionmaking framework, all 11 should be scheduled for immediate phaseout.

Table 4
Acute and Chronic Toxicity to Living Organisms

		AQUATIC ORGANISMS		TERRESTRIAL, AVIAN, AND NON-MAMMALIAN SPECIES		MAMMALS
SCORE	**LIST**	**ACUTE TOXICITY** (96-hour LC_{50}, mg/L)	**CHRONIC TOXICITY** (NOAEC, µg/L)	**ACUTE TOXICITY** (LD_{50}, mg/kg)	**CHRONIC TOXICITY** (NOAEC, mg/kg)	**ACUTE TOXICITY** (LD_{50}, mg/kg)
High	GLWQA	<1	<400	50	-	50
	OMOE	<0.1	<0.2	<1	<0.5	<0.5
	MCMR	<1	<100	<5	<5.0	<5
	BUA	<1	<100	<25	-	<25
	WMS	<1	<1.0	<25	<0.5	<25
	TSCA	<1	<100	<50	<5.0	<58
	EC	<1	-	-	-	-
	Foran	<0.001	<0.1	<1.0	<0.1	<1
	CERCLA	-	-	-	-	<0.1
Moderate	EC	1-10	-	-	-	-
	OMOE	1-10	-	-	-	-
	MCMR	10-100	-	-	-	-
	Foran	1-10	0.1-1.0	1.0-10.0	0.1-1.0	-
Low	EC	10-100	-	-	-	-
	OMOE	100-1,000	-	-	-	-
	MCMR	100-1,000	-	-	-	-
	Foran	>10	>1.0	>10	>1.0	>10

GLWQA	Great Lakes Water Quality Agreement
OMOE	Ontario Ministry of the Environment
MCMR	Michigan Critical Materials Register
BUA	Beratergremium für Umweltrelevante Altsoffe
WMS	Netherlands Chemical Substance Act
TSCA	Toxic Substances Control Act
EC	European Community
Foran	Reference (38)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act

Source: References (28) and (38).

4.5 CONCLUSIONS AND RECOMMENDATIONS

Chemical Selection

In order to focus a virtual elimination strategy on the correct substances, experts from academia, governments, industry, and other stakeholders collectively must:

- Identify criteria for use in the chemical selection and phaseout processes, and adopt uniform quantitative values for each criterion.

- Develop and recommend a uniform screening procedure to identify chemicals that meet the definition of persistent toxic substance and to schedule their phaseout.

- Develop and recommend a uniform procedure, preferably incorporating the use tree and life cycle approach described in Chapter 3, to select persistent toxic substances for phaseout.

The Task Force concludes that four criteria -- bioaccumulation factor (BAF), persistence, chronic toxicity to aquatic organisms, and evidence (if available) of specific causality and/or injury (or potential injury) to biota -- are the most important in the selection and classification process. The Task Force also proposes numerical values for BAF, persistence, and chronic toxicity, to be applied for initial screening of substances, as well as more stringent values to be applied to identify those chemicals which meet the definition of persistent toxic substance and which should be virtually eliminated.

The Virtual Elimination Task Force recommends that:

3. The Parties, in consultation with stakeholders, jointly develop, quantify, and apply criteria to screen chemicals, which will lead to development of a list of persistent toxic substances to be evaluated through the decisionmaking process, and to select persistent toxic substances for phaseout.

Since considerable work has already been undertaken to identify and develop the basis for selection criteria, the Task Force believes the criteria can be confirmed and quantified within six months after release of this report. As a point of departure, the Parties should give serious consideration to the criteria and numerical values proposed in this chapter. They should also closely examine chemical classes and processes as well as industry sectors related to the generation and use of persistent toxic substances.

Timing

In some cases, immediate sunsetting is feasible, for example, because alternatives to the particular persistent toxic substance or to a particular production process are available. However, this is not always the case. Therefore, a specific timetable should be established for the phaseout of targeted persistent toxic substances, which would allow industry and the research community an opportunity to develop suitable alternatives. The timetable should also include benchmarks to demonstrate progress toward complete phaseout.

The Virtual Elimination Task Force recommends that:

4. The Parties set specific timetables for the phaseout of persistent toxic substances not amenable to an immediate ban.

Particular attention should be focused on those persistent toxic substances which are responsible for ecosystem injury.

Immediate Action

Notwithstanding the development of selection criteria, a screening process, and a list of persistent toxic substances, the Virtual Elimination Task Force concludes that sufficient evidence exists to warrant immediate phaseout of the Water Quality Board's 11 Critical Pollutants (Table 1). The Task Force believes that application of the strategy and its decisionmaking process, as presented in Chapter 3, will achieve virtual elimination of these persistent toxic substances. The Virtual Elimination Task Force recommends that:

5. The Parties, through application of the decisionmaking process, immediately initiate measures to sunset the 11 Critical Pollutants, including all aspect of their manufacture, import, export, use, and disposal.

The Task Force is aware of the myriad of issues that must be faced and resolved to fully sunset the 11 Critical Pollutants. Among these are continued use and disposal practices, remediation, foreign use, long-range atmospheric transport, and natural occurrence. If we are serious about virtual elimination and fulfilling the requirements of the Agreement, these and other similar questions must be resolved. The use tree and life cycle approach presented in Chapter 3 is an appropriate mechanism within which to consider confounding factors. Appendix A presents further discussion of the problems and factors to consider, and the measures that can be taken when dealing with two of the Critical Pollutants, PCB and mercury. Appendix B provides a further example for application of the use tree and life cycle approach to a feedstock chemical, within the context of the virtual elimination strategy.

5. CONTAMINANT USES, SOURCES, QUANTITIES, FATE AND MODELS

5.1 INTRODUCTION

In order to implement a virtual elimination strategy it is essential to obtain an understanding of the behaviour of persistent toxic substances in the entire ecosystem. This includes how they are synthesized, produced or used, how and in what quantities they enter the ecosystem, their fate in the ecosystem as they are transported in air and water and migrate among media (air, water, sediments and biota), the extent to which virtual elimination actions will reduce contaminant levels, and how long this will take. These issues are identified in the decision-making framework depicted in Figure 1 and are the focus of this chapter.

The following definitions are used throughout this report. A **source** is defined as the origin of the persistent toxic substance. A **pathway** is the route by which the substance is delivered to the lake. A **load or input** is the amount entering the lake via a pathway. Typically, as a persistent toxic substance moves from source to pathway it becomes more difficult to control. Thus there is a strong incentive to prevent formation of the substance at the source.

This chapter gives a brief overview of the uses and sources of selected persistent toxic substances, then discusses their pathways and inputs to, as well as movement within the basin ecosystem. For details see References (39-42) and Appendix A. The main purpose of this chapter is to illustrate how a mass balance ecosystem fate model provides a quantitative link between inputs and contaminant levels in the system, identifies major inputs, and can be used to predict the ecosystem response as well as response time to changes in these inputs. Although the model does not directly relate sources to inputs (for this, additional information/models are required as discussed in References (39-42)), it provides a valuable "decision support system" to justify and promote the virtual elimination strategy.

5.2 USES, SOURCES AND FATE OF PERSISTENT TOXIC SUBSTANCES

Information on precursors (i.e. raw materials and intermediates in the manufacturing process), uses, sources, and environmental contamination is a crucial foundation for the implementation of the virtual elimination strategy, as most improvements in environmental quality will result from reduction or elimination of the first three items. Although possible, it is generally not feasible to clean up environmental "hot spots," and it may be prohibitively expensive to mitigate environmental contamination. Knowledge about the degree of inplace contamination provides a guide to what extent virtual elimination can be achieved. The fate of persistent toxic substances is important because the adverse effects that they cause are usually exhibited in the media where they reside.

Three persistent toxic substances (lead, mercury, and PCBs) illustrate the approach suggested and the problems encountered. Ultimately it will be necessary to compile similar, more detailed assessments for all substances of concern.

Polychlorinated Biphenyls (PCBs)

Total United States production of PCBs, which peaked in 1970, is estimated to have been 640,000 tonnes. Prior to 1971 PCBs were extensively used as dielectric fluids in transformers and capacitors (75% of total usage). Use as fluids in hydraulic and heat transfer equipment amounted to about 10%, while usage in diverse applications such as in carbonless copy papers, plasticizers, epoxy compounds, synthetic resins, machine and high vacuum oils, compressor oils, textile dyes, putties, waxes, and pesticides accounted for the remainder. After 1971, uses were restricted almost completely to closed electrical systems where PCBs are still used as insulators, coolants or dielectrics. In 1979, manufacture and import of PCBs were prohibited in the United States unless a petition for exemption was filed. As of 1988, about 115 companies qualified for exemptions.

PCBs were never commercially produced in Canada, but approximately 40,000 tonnes of Askarel fluids (containing 40 to 70% PCBs) were imported. In 1991, it was estimated that over 13,000 tonnes were still being used, mainly in transformers and capacitors.

A large quantity of PCBs (70,000-200,000 tonnes) have been released to the environment or disposed of in underground sites and, thus, are difficult to control or eliminate. Environmental measurements and mass balance studies clearly show the migration of PCBs through the entire environment. Although PCBs now are almost exclusively used in closed systems, spills and leaks occur, resulting in emissions to the atmosphere. PCBs may also be emitted as a result of electric power generation, fuel combustion and waste incineration. Estimates of emissions from these source categories amount to about 1,000 tonnes/year.

PCBs are also emitted to the atmosphere from contaminated soils and water bodies, landfills and waste dumps, usually as the result of past activities. Deposition and revolatilization occur enabling them to be transported long distances. Hence sources beyond the Great Lakes may impact the lakes.

Current concentrations in the basin's atmosphere range from 0.1 to 1.0 ng/m^3. PCBs are delivered by wet and dry deposition and absorbtion to the lakes and their watersheds. Once in the lake the principal fate is evaporation back to the atmosphere or settling to the bottom with subsequent burial in sediments. PCBs react or degrade very slowly. A major cause of concern is their strong tendency to bioaccumulate in fish. Fish-eating animals (including humans) are thus exposed to elevated levels of PCBs.

Lead

Most uses of lead are consumptive, i.e. there is little closed-cycle use or lead recycling. Utilization results in dissipation of lead in the environment. Total lead consumption in Canada declined from over 125,000 tonnes in 1982 to about 68,000 tonnes in 1991. Consumption in the United States in 1986 was 1,125,000 tonnes. A major use was as an anti-knock agent (tetraethyl lead) in gasoline. Other uses include leaded glass, storage batteries, plumbing, and lead oxides and pigments in paint. Lead is released as a waste byproduct from coal and oil combustion, metal refining and fabricating, cement manufacture and waste incineration. Lead is also transported in the atmosphere and is deposited by wet and dry deposition. Sources beyond the basin provide input to the lakes. Preliminary calculations, performed by the U.S. Environmental Protection Agency (EPA), indicate that sources 500 to 1000 km to the south of Lake Superior contributed more than 30% of the total deposition to the lake in 1985. Most lead entering lakes settles to the bottom. There has been a marked reduction in lead levels in the atmosphere in the last decade; presumably, this will result in reduction in lead levels in the lakes, their surficial sediments and in biota. This reduction is due to a decrease in emissions (Figure 3), primarily because of the introduction of unleaded gasoline.

Mercury

Uses of mercury are also mostly consumptive, although there is more closed-system use and recycling than for lead. Mercury is currently not commercially produced in Canada. Quantities needed are imported. Canadian consumption decreased from over 41 tonnes in 1985 to about 9.3 tonnes in 1991. In 1989 total United States consumption was about 1,350 tonnes.

Mercury is widely used within the industrial, medical, agricultural, and consumer sectors; over 2,000 applications have been identified. In the United States the major use sectors in 1988 were "chemical and allied product": chlorine and caustic soda (28%), batteries (28%), and paint (12%). Most biocidal and fungicidal uses and use in paints have now been cancelled. Consumption in Canada was allocated in 1991 as 42% to electrical apparatus, industrial and control instruments; and 58% to electrolytical preparation of chlorine, caustic soda, and other uses.

Mercury is released as a waste byproduct in coal and oil combustion, metal smelting and battery manufacturing, waste incineration, and from discarded batteries and other consumer goods. Implementation of pollution control or closure of facilities for production of chlorine and caustic soda has reduced releases to the environment from this sector. Total releases to the atmosphere in 1992 were estimated to be about 450 tonnes in the United States and 26 tonnes in Canada.

Mercury can exist in elemental, inorganic ion, and organic forms. These forms inter-convert and have different properties and toxicities. Atmospheric residence times for the species also differ, which means local as well as remote sources contribute to the atmospheric input to the lakes. Elucidating the fate of mercury in the environment is thus difficult since, like PCBs, it is subject to active exchange between air and water, and sediments and water, and it bioaccumulates. Although there are natural sources of mercury, much of the chemical released from vegetation and soil has been deposited as a result of previous anthropogenic activity.

Sources and Transport

The atmosphere is a significant pathway by which persistent toxic substances enter the Great Lakes. Municipal and industrial sources as a whole also contribute sizeable quantities. As the Task Force's source investigation revealed for Lake Superior, and other studies have shown (here and elsewhere), there are no large <u>and</u> easily reducible <u>individual</u> sources of these chemicals discharging directly to the Great Lakes, and the impact from emissions from <u>individual</u> sources to the atmosphere is not known. Most easily reducible sources have already been subjected to controls, and few simple options remain that would have significant impacts. Remaining sources tend to be widely dispersed and, in the case of air emissions, often not in the Great Lakes basin. Hence, control strategies must target several sectors. Table 5 lists the pathways by which PCB, mercury, and lead reach Lake Superior. For each Great Lake, the percentages and absolute amounts differ, but the bottom line is that these chemicals are still not yet at acceptably low levels. Further reduction is needed. Points of intervention to lower or eliminate inputs are discussed in Appendix A.

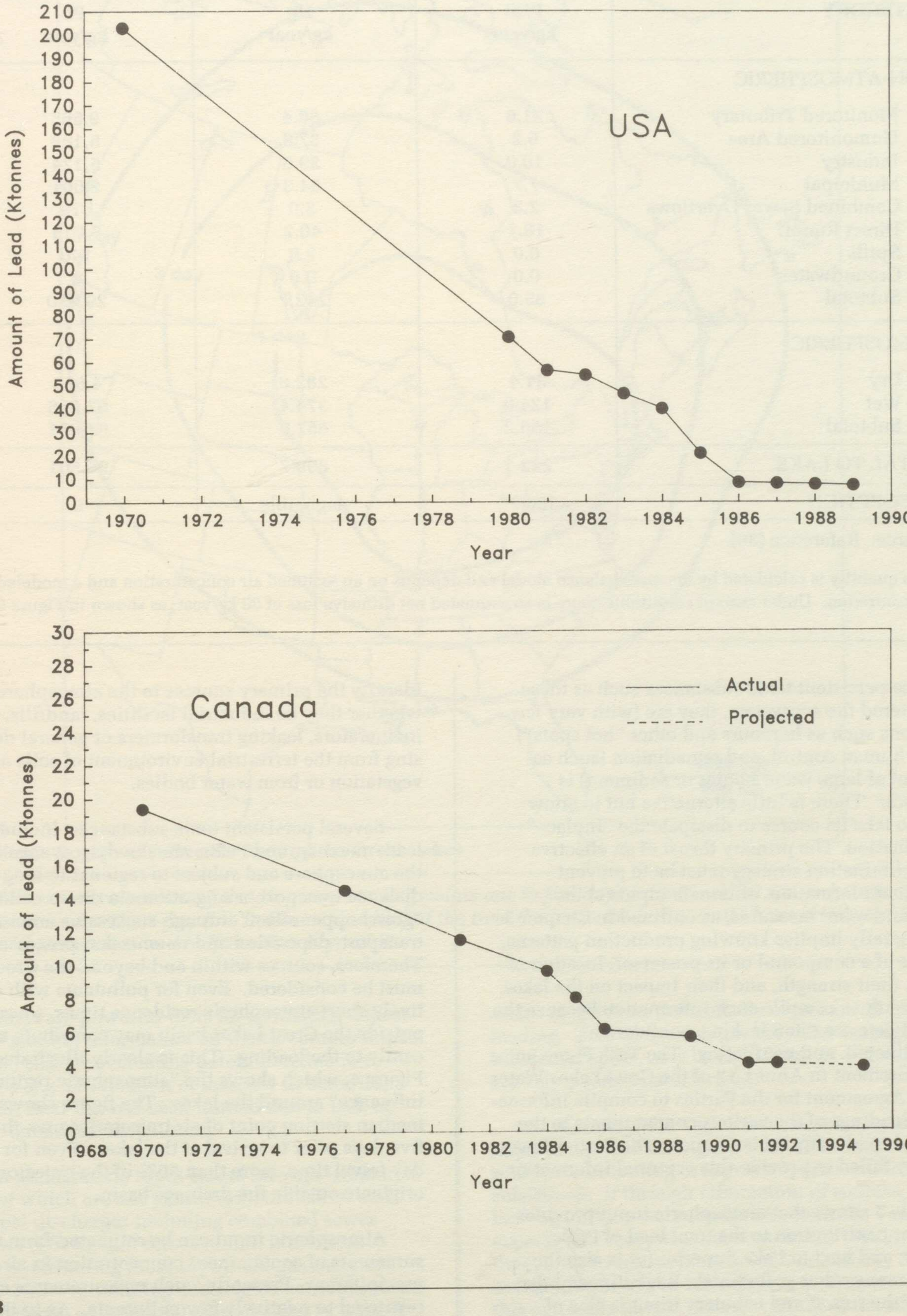


Figure 3
Lead Emission Trends in the United States and Canada

Table 5
Summary Estimates on Sources and Loadings of PCBs, Mercury and Lead to Lake Superior

CATEGORY	PCB kg/year	Hg kg/year	Pb kg/year
NON-ATMOSPHERIC			
Monitored Tributary	21.6	86.4	9,665
Unmonitored Area	6.2	37.8	5,189
Industry	10.0	39.0	5,124
Municipal	7.7	34.3	2,001
Combined Sewer Overflows	2.3	3.0	619
Direct Runoff	18.1	40.2	7,013
Spills	0.0	2.0	140
Groundwater	0.0	0.0	0
Subtotal	65.9	242.7	29,750
ATMOSPHERIC			
Dry	31.4	282.6	4,655
Wet	124.8	374.4	62,396
Subtotal	156.2	657.0	67,051
TOTAL TO LAKE	222.1	899.7	96,801
ABSORPTION	136.7*	negligible	0

Source: Reference (39).

* This quantity is calculated by the mass balance model and depends on an assumed air concentration and a modeled water concentration. Under current conditions, there is an estimated net diffusive loss of 60 kg/year, as shown in Figure 5.

Once persistent toxic substances such as these have entered the ecosystem, they are (with very few exceptions such as harbours and other "hot spots") beyond human control, and remediation (such as treatment of large water bodies or sediment) is unrealistic. There is little alternative but to allow nature to take its course to dissipate the "inplace" contamination. The primary thrust of an effective virtual elimination strategy must be to prevent contaminant formation, eliminate inputs at the source, and other measures, as outlined in Chapter 3. This generally implies knowing production patterns, use trees of a compound or its precursor, location of sources, their strength, and their impact on the lakes. It is difficult to compile such information because the required data are often lacking, confidential, uncoordinated, and conflicting. The Task Force notes the requirement in Annex 12 of the Great Lakes Water Quality Agreement for the Parties to compile information on loadings of the various contaminants to the lakes and to identify their sources. The Parties have generally failed to provide this essential information.

Table 5 shows that atmospheric input provides the major contribution to the total load of PCBs, mercury, and lead to Lake Superior (as is also the case for many other pollutants). It is estimated that much of the runoff and tributary input is also of atmospheric origin. There is a clear need to better identify the primary sources to the atmosphere, i.e. whether they be industrial facilities, landfills, incinerators, leaking transformers or general degassing from the terrestrial environment of soils and vegetation or from water bodies.

Several persistent toxic substances, including lead, mercury, and PCBs, are slowly scavenged from the atmosphere and subject to regional to long distance transport or migration via the so-called "grasshopper effect" through successive emission, transport, deposition and re-emission processes. Therefore, sources within and beyond the Great Lakes must be considered. Even for pollutants with relatively short atmospheric residence times, sources outside the Great Lakes basin may contribute significantly to the loading. This is clearly illustrated in Figure 4, which shows the "atmospheric region of influence" around the lakes. The figure shows the median starting point of air trajectories one, three and five days prior to arrival at the lakes. Even for a one-day travel time, more than 50% of the trajectories originate outside the drainage basin.

Atmospheric input can be estimated from measurements of contaminant concentration in air and precipitation. Presently, such measurements are restricted to relatively few pollutants. As in the field of acid deposition, atmospheric transport and deposi-

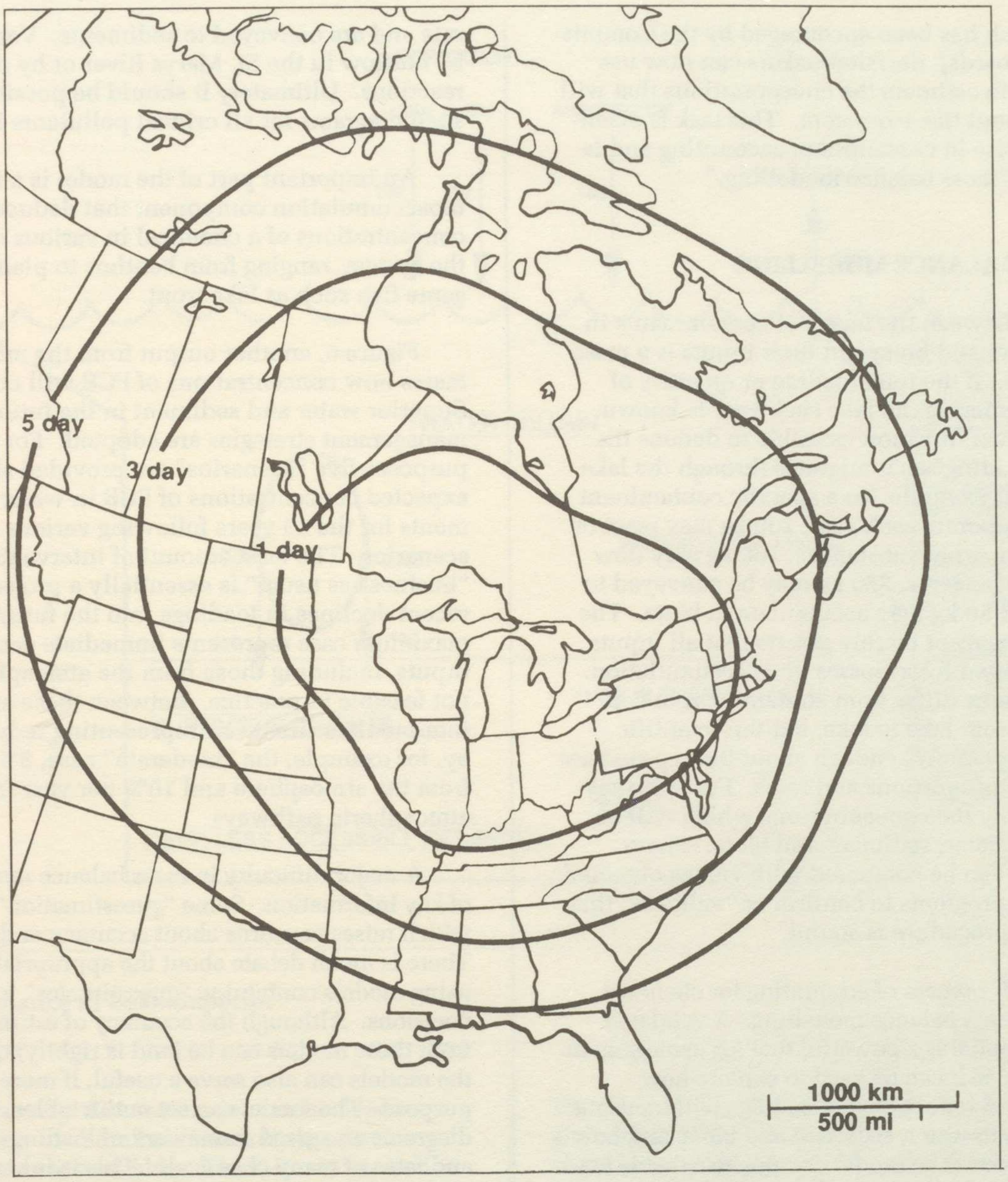


Figure 4
Atmospheric Region of Influence Around the Great Lakes

Lines of the median location of the air parcel starting points one to five days prior to arrival somewhere in the Great Lakes basin. The 3-day line indicates that half of the time the air in the basin would have originated 3 days earlier within that line and half the time beyond it.

tion models are powerful tools for estimating deposition, for gaining information on which sources impact the lakes, and for evaluating potential reduction scenarios (e.g. elimination of mercury in batteries). However, their use has been limited due to lack of suitable emissions inventories.

Non-atmospheric input enters through tributaries (many of which are not monitored), industrial and municipal discharges including combined sewer overflows (CSOs), and direct runoff. Individual sources contributing these inputs are generally not known. However, mining and related activities result in the majority of industrial mercury and PCB loads in the Lake Superior basin, while the pulp and paper sector contributes the majority of industrial lead loading. Two categories, groundwater seepage and accidental spills, may be significant in some cases but are very poorly characterized.

In summary, the Task Force emphasizes the importance of obtaining reliable information on sources contributing to inputs of persistent toxic substances. If through elimination of sources, the loading of PCBs were reduced by half, the Task Force expects that ecosystem concentrations would, over time, drop to approximately half, or halfway to the background levels in Lake Superior. One reason for this emphasis now is that, as a result of decades of research into contaminant fate in lake ecosystems (much of which has been encouraged by the Commission and its Boards), decisionmakers can now use loadings data to estimate the concentrations that will result throughout the ecosystem. This task is essentially an exercise in contaminant accounting and is referred to as "mass balance modelling."

5.3 MASS BALANCE MODELLING

The link between the levels of contaminants in water, sediment and biota and their inputs is a mass balance model. If the total loading or quantity of contaminant entering the lake each year is known, e.g. 1,000 kg/year, it is now possible to deduce the fate of this "loading" as it migrates through the lake ecosystem. For example, for a specific contaminant 300 kg may evaporate each year, 200 kg may react or degrade to form other substances, 100 kg may flow out of the lake in rivers, 350 kg may be conveyed to sediments, and 50 kg may accumulate in biota. The mass balance concept merely asserts that all inputs must be accounted for as losses or as accumulation. These proportions differ from contaminant to contaminant and from lake to lake, but the scientific community now knows enough about these processes to estimate the proportions and rates. Further, they can also estimate the concentrations which will be established in water, sediment and biota. These estimates can then be compared with values obtained by monitoring programs to confirm or "validate" that the modelling procedure is sound.

This overall process of accounting for chemical fate is termed mass balance modelling. A validated mass balance model is a powerful tool for management purposes, because it can be used to explore how various proposed reductions in loadings will translate into reductions in water, sediment and biota, and how long this will take. The model documents what is (and is not) achievable, and when it is achievable as a result of various proposed actions to reduce or eliminate sources of chemicals. It can define achievable targets in terms of chemical concentrations throughout the ecosystem and times required to meet these targets. It can signpost the road towards virtual elimination.

As part of the Task Force's investigation a mass balance model of chemical fate was developed specifically for virtual elimination purposes and applied to PCBs, mercury and lead in Lake Superior. The model structure and results were distributed and peer reviewed in December 1992. Details of the model and the assumed loadings are found in References (41,42).

Figure 5 is a specimen mass balance diagram for PCBs in Lake Superior. It shows the routes by which PCBs are believed to enter the lake and how this persistent toxic substance migrates to sediments and back to the atmosphere. It is noteworthy that substantial fractions of the PCB entering the lake evaporate and are conveyed to sediments. Very little leaves by outflow in the St. Marys River or by degrading reactions. Ultimately it should be possible to obtain such diagrams for all critical pollutants in all lakes.

An important part of the model is a food chain, bioaccumulation component that deduces the likely concentrations of a chemical in various organisms in the system, ranging from benthos to plankton and to game fish such as lake trout.

Figure 6, another output from the model estimates how concentrations of PCB will change in Lake Superior water and sediment in the future, if certain management strategies are adopted. For illustrative purposes five "scenarios" are provided showing the expected concentrations of PCB in water and sediments for the 15 years following various elimination scenarios. The least amount of intervention or "business as usual" is essentially a projection of recent declines in loadings into the future. The maximum case represents immediate cessation of all inputs, including those from the atmosphere. This is not feasible in practice. Between these are three intermediate situations representing reduced loadings by, for example, the "moderate" case, 8% per year from the atmosphere and 10% per year from non-atmospheric pathways.

A major difficulty in mass balance modeling is lack of key information. Some "guesstimation" is needed, which raises concerns about accuracy and credibility. There is much debate about the appropriateness of using models containing "guesstimates" to support decisions. Although the accuracy of estimates arising from these models can be (and is rightly) questioned, the models can also serve a useful, if more modest, purpose. The model can set out in tables, charts or diagrams an agreed framework of loadings, pathways and fates of many chemicals. This is inherently valuable as a basis for communication, understanding, discussion and, ultimately, decisionmaking. Mass balance models of lake processes, when coupled with loading models that estimate inputs to the lakes (such as air deposition and surface runoff) and link these inputs with contributing sources, are powerful tools that are fundamental and essential in the decisionmaking process.

A point of consensus reached during the scientific peer review of the Lake Superior model (42) is worth emphasizing. No claim is made that the model can depict or predict the fate of persistent toxic substances with high accuracy. However, the modellers are convinced that models such as this are now sufficiently accurate that they can and should be used for management purposes. In other words, while better models are still needed, implementation of the virtual elimination strategy should not be held up for this reason. Scientists and decisionmakers know enough to move forward, and formulate strategies that can be adequately supported by existing models.

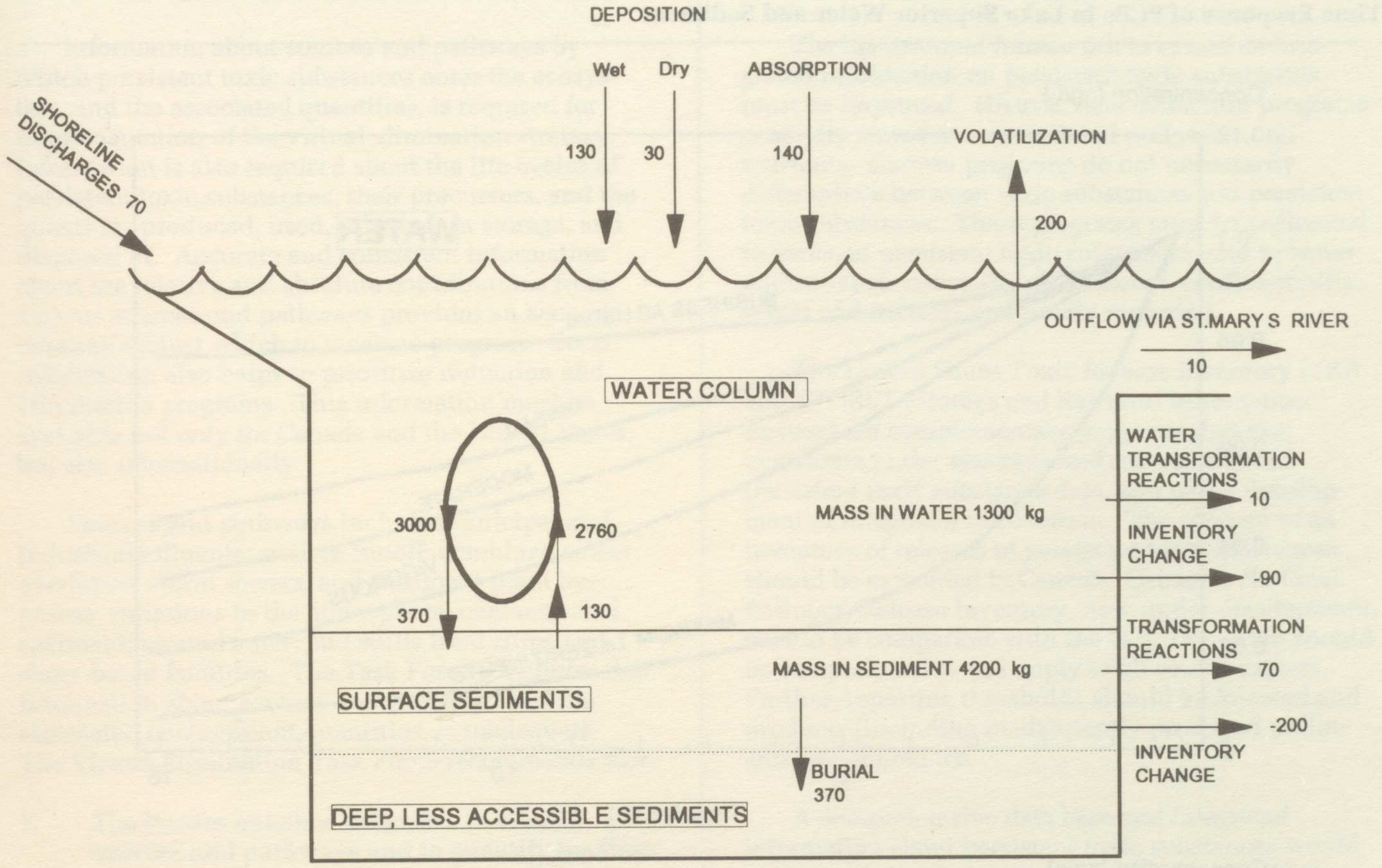


Figure 5
PCBs Mass Balance in Lake Superior

It is noteworthy that the model can be used to evaluate the fate of chemicals when little or no monitoring data are available. Thus, it can be used as a screening tool to determine which pollutant to monitor, control or eliminate and the time frame for these actions. The model can serve as an early warning device to indicate emerging problems and can be used to assess the likely fate of new chemicals.

5.4 CONCLUSIONS AND RECOMMENDATIONS

Global Considerations

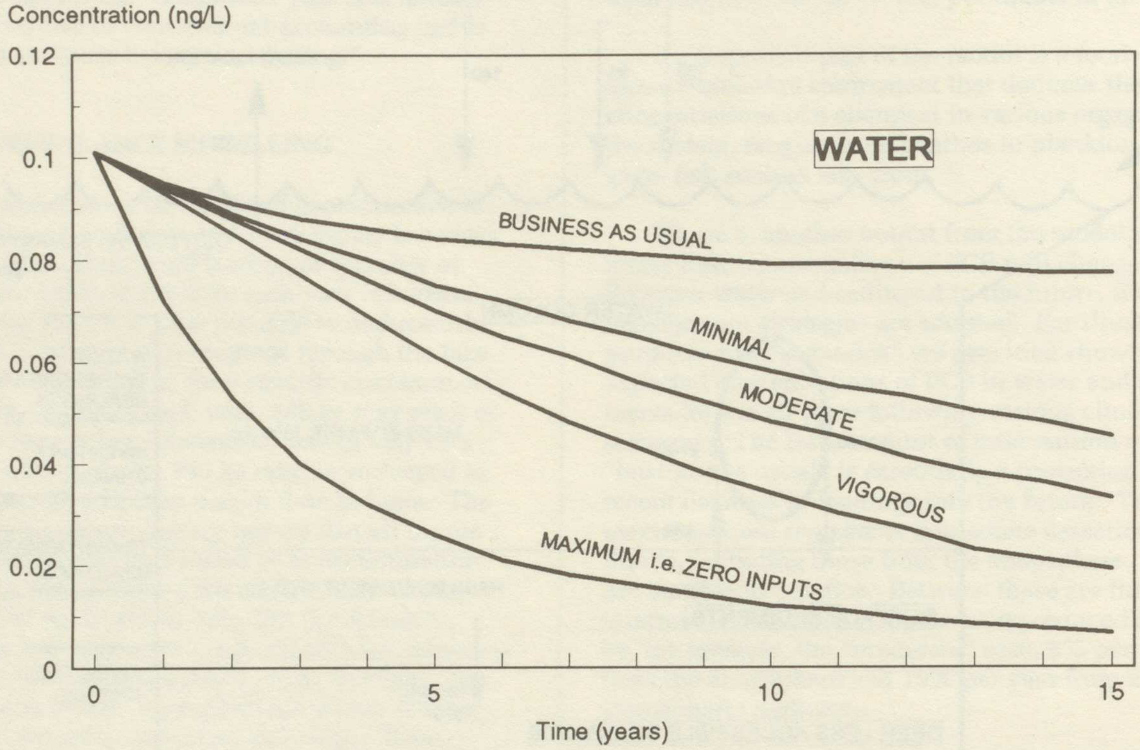
The Task Force notes that large quantities of some persistent toxic substances (such as DDT), although "banned" for domestic use in the United States and Canada, are still produced in the United States for export, as well as produced and used in a number of other countries. While charged to investigate the Agreement requirement to virtually eliminate the input of persistent toxic substances to the Great Lakes Basin Ecosystem, the Task Force concludes that a Great Lakes regional focus is clearly insufficient. The virtual elimination strategy must be applied globally, because of the ability of persistent toxic substances to disperse globally, in large measure through long-range atmospheric transport.

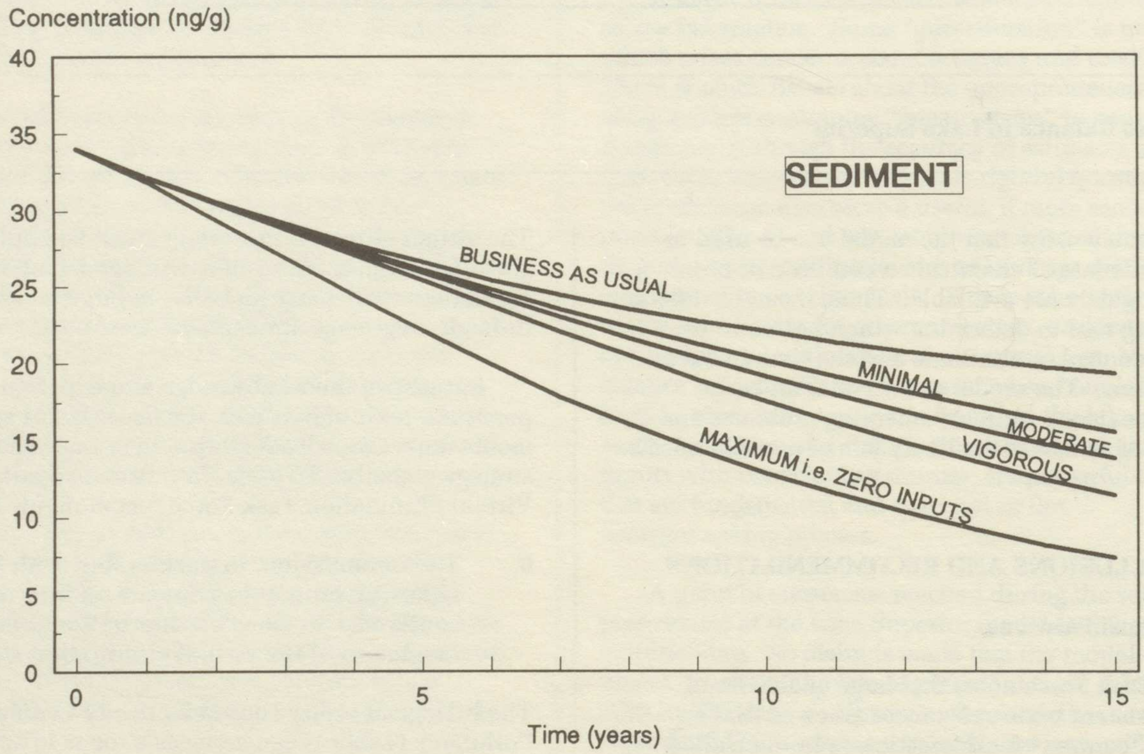
Because of their knowledge and experience with persistent toxic substances, the Great Lakes governments must take a leadership role to implement the strategy globally. To assist in this endeavour, the Virtual Elimination Task Force recommends that:

6. **The Commission, in partnership with Great Lakes governments, convene an international conference to focus on international implementation of the virtual elimination strategy.**

The biological injury caused by the 11 Critical Pollutants (Table 1) can serve as a focus to actively promote the need for the strategy, as well as the means to achieve virtual elimination. The conference can also serve as a forum to obtain quantitative information about the amounts of persistent toxic substances in use globally. See also further discussion in Chapter 6.

Figure 6
Time Response of PCBs in Lake Superior Water and Sediment





Business as usual:	No measures are taken.
Maximum:	Zero inputs of PCBs from atmospheric and land sources.
Minimal:	Loadings of PCBs from atmospheric and land sources are dropping at a rate of 5% per year.
Moderate:	Loadings of PCBs from atmospheric and land sources are dropping at rates of 8% and 10% respectively.
Vigorous:	Loadings of PCBs from atmospheric and land sources are dropping at rates of 15% and 20% respectively.

Sources of Persistent Toxic Substances

Information about sources and pathways by which persistent toxic substances enter the ecosystem, and the associated quantities, is required for implementation of the virtual elimination strategy. Information is also required about the life cycles of persistent toxic substances, their precursors, and the quantities produced, used, released, in storage, and disposed of. Accurate and consistent information about the relative and absolute contributions from various sources and pathways provides an accurate baseline against which to measure progress. Such information also helps to prioritize reduction and elimination programs. This information must be available not only for Canada and the United States, but also internationally.

Sources and pathways include municipal and industrial effluents; surface runoff; combined sewer overflows, storm sewers, and treatment plant bypasses; emissions to the atmosphere; contaminated sediment; groundwater; and spills from ships and shore-based facilities. The Task Force concludes that information about sources and pathways and the associated contaminant quantities, is inadequate. The Virtual Elimination Task Force recommends that:

7. **The Parties enhance programs to identify sources and pathways and to quantify loadings of persistent toxic substances to the Great Lakes Basin Ecosystem.**

8. **The Parties compile reliable and complete quantitative information for the life cycle of persistent toxic substances and their precursors.**

This information must include, as a minimum, the amounts of persistent toxic substances produced, used, released, and disposed of, as well as their fate in the ecosystem. Further, the information must be integrated and must be readily accessible by the public.

Particular emphasis must be placed on the atmosphere, which is the dominant pathway by which many persistent toxic substances reach the Great Lakes. Since sources within and outside the basin contribute, the virtual elimination strategy cannot be confined to the Great Lakes basin. The Virtual Elimination Task Force recommends that:

9. **The Parties develop quantitative information about the release of persistent toxic substances to the atmosphere from all sources.**

This information must include the form and speciation of the substances being emitted. Further, the information base must be sufficient to determine and differentiate the impact of local versus distant sources of persistent toxic substances, including identification of major sources and source categories.

Data and Information Management

The institutional framework to assemble integrated information on persistent toxic substances must be improved. Historic data collection programs generally aimed at conventional pollutants and nutrients. Current programs do not necessarily differentiate between toxic substances and persistent toxic substances. These programs must be redirected to focus on persistent toxic substances, and to better address such issues as public access, confidentiality, levels of detection, and timely reporting.

The United States Toxic Release Inventory (TRI) and STORET (Storage and Retrieval Information System) are complementary programs that can contribute to the assembly and management of persistent toxic substance data, and to the development of integrated information. The concept of an inventory of releases of persistent toxic substances should be expanded to Canada. Canada's National Pollutant Release Inventory, now under development, should be compatible with the U.S. TRI. Both should be comprehensive and apply to all source sectors. Further, reporting thresholds should be lowered and products (including inadvertently produced pollutants) accounted for.

A comprehensive data base and integrated information about persistent toxic substances would underpin a decision-support system that could be used, for instance, to identify and substantiate remedial actions, with associated schedules and priorities; project future loadings and concentrations of persistent toxic substances, in the form of agreed-to targets towards virtual elimination; and facilitate assessment of the effectiveness of programs undertaken pursuant to the Agreement.

Mass Balance Ecosystem Fate Models

Mass balance-ecosystem fate models are valuable tools to implement the virtual elimination strategy. Their use, in conjunction with source identification, should be encouraged; however, there is a need to continue to develop, review, refine, and validate lake and food chain models for more chemicals in more lakes. Consensus exists that present models are accurate enough to estimate contaminant fate now and in the future, as remedial measures are implemented. The models can be used to project future ecosystem concentrations and response times, as a result of reduced inputs of persistent toxic substances to the ecosystem. Models can also be used proactively to identify new pollutants and future problems. The Virtual Elimination Task Force recommends that:

10. **The Parties use mass balance-ecosystem fate models as tools in the virtual elimination strategy not only for contaminants of present concern, but also proactively to identify new pollutants and future problems.**

Improved source information and a better understanding of physical, chemical, and biological processes that control contaminant fate in the lakes would improve projections of the rate and extent of ecosystem response.

6. EVALUATION OF LEGISLATION, REGULATIONS AND PROGRAMS

6.1 INTRODUCTION

This chapter builds and elaborates on the recommendations made by the Task Force in its Interim Report (1) concerning legislative and policy opportunities to implement the virtual elimination strategy. It considers and includes the work submitted by contractors (43-46) and the discussions and conclusions from a workshop held by the Commission's Great Lakes Water Quality Board (47-48).

As noted in Chapter 3, approaches pertaining to persistent toxic substances have evolved over time. As these approaches evolve, so too must the supporting legislative and regulatory framework. The challenge for the current regulatory framework is to move from pollution control to prevention. Within that context, the question is whether existing regulatory regimes provide the authority to act and focus on persistent toxic substances.

In reviewing the legislative and policy framework governing persistent toxic substances in the Great Lakes, a number of questions were asked to focus the discussion:

- Do the governments have the legal authority to implement the goal of virtual elimination?
- If yes, what are the impediments to furthering the concept?
- What reforms, both in the long and short terms, are necessary to fully realize the goal?

6.2 LEGAL AUTHORITY TO ACHIEVE THE VIRTUAL ELIMINATION GOAL

Do governments in the Great Lakes basin have the legal authority to address all areas pertaining to the use, generation, release, and disposal of persistent toxic substances, including their end products? A number of studies examining that question give an unequivocally positive response (47).

In the United States, the Clean Water Act's goal was the elimination of discharges by 1985, and the Toxic Substances Control Act (TSCA) was intended as a mechanism to eliminate various chemicals. The original legislative intent is well documented. Since passage of the original 1972 Clean Water Act, the United States has amended the law twice to clarify unequivocally that it is the policy of the United States government to implement the goals and objectives of the Great Lakes Water Quality Agreement (sec. 118, 1987 and the Critical Programs Act, 1990). The United States is currently preparing regulations and guidance (the Great Lakes Water Quality Initiative (GLI)) aimed at fulfilling implementation of the Agreement.

The extent of legal authority of the states to fully implement a virtual elimination strategy is less clear. However, there are a number of legislative and policy initiatives unquestionably within their power.

Similarly in Canada, studies have concluded that the federal government has the power to develop regulatory strategies to achieve the goal of virtual elimination. The Canadian Environmental Protection Act (CEPA), for example, has broad language and vests consideration powers with the Ministers of the Environment and National Health and Welfare. Preparations for a five-year review of CEPA are underway, as mandated under the legislation. One of the focal points for the review is how best to incorporate a pollution prevention regime into this statute or other federal statutes. Unlike the United States, it is clear that any comprehensive virtual elimination strategy in Canada must be a cooperative effort between provinces and the federal government.

Despite having the legal authority to implement the virtual elimination strategy, there is a broad consensus that the governments have not fully acted on their authority. The implementation of laws in the United States and Canada has been a failure, from the standpoint of developing a comprehensive and effective virtual elimination strategy. Despite progress that has resulted from existing laws, goals such as zero discharge have been overlooked and practically forgotten. TSCA has become, at best, a tool to screen the introduction of new chemicals. It has only been used to limit the use and manufacture of PCBs. CEPA has been incredibly slow and cumbersome, and seemingly ineffective.

The draft GLI will not, in its present form, implement the zero discharge goal. However, discussions are underway to proceed to the next phase of the GLI and "sunsetting" is on the table. It is too early to comprehend the effect of recommendations flowing from the CEPA review.

Hence, the issue has not been the lack of legal authority, but lack of effective utilization of the powers before the governments. In its advice to the Task Force:

"The [Water Quality] Board concludes that, in terms of authority contained in the legislation, the two federal governments have adequate mandates and authority to implement the policy contained in the Great Lakes Water Quality Agreement concerning the virtual elimination of discharges of any or all persistent toxic substances.... The Board, however, recognizes that there are significant barriers to the effective implementation of this authority" (47).

While there is legal authority, the need for interjurisdictional coordination, especially within Canada, cannot be overemphasized. This issue is raised again below.

What then are the reasons, impediments, or gaps in the regulatory framework to achieve the virtual elimination goal? Many of these were identified in the Task Force's Interim Report (1).

6.3 GAPS OR IMPEDIMENTS TO THE FURTHERANCE AND IMPLEMENTATION OF THE VIRTUAL ELIMINATION GOAL

Upon review of the contractors' reports and other literature on the subject, a number of important gaps and impediments were identified.

- **Gaps in important baseline information**. Despite years of study, there are inconsistencies in the collection and reporting of data in the Great Lakes. There are limited, if any, basinwide data on sources, uses, and releases for a whole range of chemicals, processes, and products. One of the reasons for these data gaps rests with the traditional view that the onus is on government to prove harm rather than on those producing, using, or releasing chemicals.

- **Gaps addressing certain pathways and receptors**. A number of pathways and receptors have not been taken into account in a comprehensive way by the regulatory systems in the basin. For example, gaps in pathways include prevention of the use of persistent agricultural pesticides, and contaminated sediment reactivation. Gaps in receptors include restoration of groundwater and sensitive populations of wildlife and humans.

- **Barriers arising from jurisdictional diversity**. The lack of coordination among many jurisdictions within the Great Lakes basin has led to a patchwork of laws, inconsistent enforcement and sometimes confused, if not conflicting regulatory approaches. Another element, however, is the lack of **bilateral** effort to develop a mutual regime for virtual elimination and of leadership to develop a **multilateral** regime (be it North America or beyond) to deal with sources outside the Great Lakes basin.

- **Barriers arising from the lack of a multi-media approach**. Laws governing air, water and wastes are developed and implemented independently and in isolation. This media-specific approach has led to inconsistencies among the standards governing a single chemical, gaps in coverage, and different bases or criteria for regulation.

- **The limits of the "acceptable level of pollution" approach**. The vast majority of laws in the Great Lakes still retain the pollution control approach that assumes there is an acceptable level of inputs for all chemicals. The governments' "pollution prevention" approach generally pertains to **control** (rather than prevention), focuses on **releases** (rather than uses), and attempts to determine **acceptable** levels rather than elimination requirements. This is inconsistent with the Task Force's concept of prevention (see Chapter 3).

- **A singular chemical-by-chemical focus**. Most regulatory regimes focus on a chemical-by-chemical regulatory approach rather than examining mixtures and classes of chemicals, or products.

- **The failure to recognize, for the most part, the distinction between a toxic substance and a persistent toxic substance.** This pertains not only to current government programs but also to policymakers at the highest level of government.

If these are the gaps and barriers, then how are stakeholders to develop the next generation of environmental laws governing persistent toxic substances? In Chapter 3, it was noted that many of the weaknesses, gaps and failures noted above relate to the **pollution control** phase of environmental law. It is imperative that the second phase (**pollution prevention**) and the third phase (**product/material use**) be developed and implemented as quickly as possible.

6.4 NECESSARY SHORT- AND LONG-TERM REFORMS TO FULLY REALIZE THE VIRTUAL ELIMINATION GOAL

The virtual elimination strategy must be implemented at all levels. Hence, these reforms work at all levels.

International/Multilateral Sunset Chemical Regime

Jurisdictions in the Great Lakes basin can take significant actions toward the virtual elimination goal, but they must also seek international cooperation. The Great Lakes governments and institutions must take a leadership role. The Task Force supports:

- **International leadership**. The Great Lakes governments, under the auspices of the International Joint Commission, must take a leadership role in developing an international regime for persistent toxic substances.

- **Key points for a multilateral regime**. The focal points for this regime should include:

  - A multilateral data bank for loading and source data (including release inventories).

  - An international sunset regime.

  - Technology transfer, development and substitution research.

- **International sunset chemical conference**. To further these ends, the Commission should hold an international sunset chemical conference, with participants to include high level officials from outside the basin.

Development of a Bilateral Virtual Elimination Regime

Despite many recommendations from the Commission, it is surprising and disappointing that a bilateral strategy for persistent toxic substances still does not exist. The focus of such a bilateral strategy is outlined below.

- **Great Lakes toxic use and release inventory**. While the United States has had the Toxic Release Inventory (TRI) for some years, Canada will only have a comparable program, the National Pollutant Release Inventory (NPRI), in 1993. Little attention has been paid to making these programs compatible, for example to compare loadings among Great Lakes jurisdictions. The United States and Canada should revise their reporting requirements under the TRI and NPRI to provide consistent, compatible information on releases of persistent toxic substances, and broaden the lists of reportable chemicals in both countries to include all persistent, bioaccumulative chemicals on the Water Quality Board's 1986 Working List of [362] Chemicals in the Great Lakes Basin (27).

- **Great Lakes permit and approval registry**. A binational process should be initiated to register all approvals pertaining to the use and release of persistent toxic substances. This registry should be coordinated with the release inventory.

- **Bilateral sunset chemical process**. Clearly, elimination strategies must be implemented federally and state/provincially. However, there must be bilateral cooperation, coordination and evaluation of these programs. As such, the bilateral strategy should include:

  - Development of a list of chemicals targeted for phase-out.

  - Development of a more comprehensive list, with criteria, that will provide a springboard to examine classes/mixtures of chemicals, processes and products (see Chapter 4).

  - Bilateral effort to develop "chemical profiles" (i.e. a description of chemicals from their origins through to their end-uses, sometimes called use trees). These profiles would provide an opportunity for governments to examine the legitimacy of certain processes and chemicals and where in the use phase of the chemical the product/process/chemical should be regulated.

- **Great Lakes pollution prevention institutes**. Efforts should be made, in cooperation with universities on both side of the border, to establish programs to train agency staff, industries and interested members of the public on pollution prevention. These centres should be fully integrated into the university system and interdisciplinary in nature.

- **Great Lakes clean industries initiative**. Traditionally, it has been argued that environmentally sound industries are also the most profitable. Hence, at a bilateral level, a coordinated industrial strategy is needed to encourage and indeed force industries to develop cleaner production processes through appropriate industrial strategies. Such strategies would also deal with transition, including labour issues. The industrial strategy would work toward clean production and the development of clean technologies based on pollution prevention. Another part of this industrial strategy is a product/material use policy.

6.5 DEVELOPMENT OF VIRTUAL ELIMINATION STRATEGIES WITHIN EACH JURISDICTION

The gaps and impediments identified in current regulatory approaches will only be dealt with when each jurisdiction closely examines its own laws and policies to ensure that the virtual elimination goal is met. For that assessment, a number of elements must be in place.

- Every jurisdiction should examine its laws and policies and ensure that they incorporate a **pollution prevention and elimination regime** with the following elements: goals and objectives, chemical screening criteria, sunsetting component, sunrise component, toxic use reduction measures, pollution prevention planning, reporting requirements, technical assistance, and material use study. Only a few jurisdictions have toxic use reduction laws in place, and even these fall short of including all of these elements.

- The **sunset chemical component** must be comprehensive and go beyond focusing only on specific chemicals to include families of chemicals. Reverse onus and weight of evidence principles must be employed to deal with data gaps.

- Each jurisdiction should set specific **toxic use reduction targets** on a sector-by-sector and/or a chemical basis. Progress toward these targets should be made publicly available and monitored. Further, reduction targets should be integrated into the permitting and approval processes.

- Each jurisdiction should develop a **pollution prevention planning and reporting regime**. Such regimes are now operating in a number of U.S. states. In effect, the requirements mandate that facilities plan for pollution prevention, with technical assistance provided by relevant agencies.

6.6 CONCLUSIONS AND RECOMMENDATION

The Virtual Elimination Task Force concludes that governments have the legal authority to implement the virtual elimination strategy, but have not acted on their authority. As described above, the Task Force has identified gaps and impediments that hinder achievement of virtual elimination, but a number of short- and long-term reforms could help realize the virtual elimination goal.

The Virtual Elimination Task Force recommends that:

11. The Parties review their legal framework for dealing with persistent toxic substances and, if necessary, promulgate legislation to remove barriers and to promote implementation of the virtual elimination strategy.

The legislation should promote reduced use of persistent toxic substances, examination of product/material use, sunrise/sunsetting, and pollution prevention to reduce and ultimately eliminate creation of persistent toxic substances. The legislation should also promote establishment and conduct of programs that provide requisite data and information, as described above.

As part of the approval process for allowing releases to the ecosystem, releases must not be allowed to increase from present loadings. Future approvals must include reduced limits as part of the racheting down process toward virtual elimination, and approvals will only be given if use-reduction plans have been submitted for persistent toxic substances.

7. THE ROLE OF TECHNOLOGY

Achieving virtual elimination of persistent toxic substances requires accurate assessment and definition of environmental impacts, their causes and their mitigation. It requires use of existing, new and improved treatment processes and application of pollution prevention processes. In particular, technology can help to achieve virtual elimination by focusing on:

- Remediation and containment of contaminants in sediment, groundwater, waste disposal sites, and storage.
- Treatment and control of releases (point and nonpoint) to water, air, and land.
- Prevention, e.g. change to production processes, raw materials, and product formulation. These must be developed and fully evaluated to ensure that replacement materials or processes do not produce their own undesirable environmental impacts.
- Destruction of existing persistent toxic substance storehouses.

The ability to isolate, treat or remove existing persistent toxic substance storehouses must be developed. These needs require application of existing technological resources and, in many cases, the development of new ones. More specific discussion of these needs is presented below.

7.1 ANALYTICAL TECHNOLOGIES

The first step in solving an apparent environmental impact problem is to use, or develop as needed, analytical techniques that will clearly isolate potentially responsible materials. Followup evaluations using advanced chemical analysis and organism response assessment techniques are needed to accurately define the cause and scope of the problem.

Great advances in analytical capabilities have been made in recent years. Scientists can now detect the presence of some substances (i.e. organohalogens) in the sub-part per trillion concentration range. Similar advances in low-level detection have not been made for non-halogen-containing chemicals. Scientists have begun to develop bioindicators that may be useful in assessing impacts (see Chapter 10). Further understanding, validation, development, and application of these technologies can prevent costly mistakes which can result from attempting to solve the wrong problem due to a lack of knowledge regarding causes.

7.2 CHEMICAL EVALUATION TECHNOLOGIES

To avoid releasing new persistent toxic substances into the environment, predictive technologies and screening techniques must be employed to evaluate new materials (see Chapter 4). Once substances determined to be persistent toxic substances are identified, decisions regarding production approvals or control requirements (see below) can be made.

Some technologies are the same or similar to those analytical techniques noted above. Other screening technologies to determine solubilities and other properties can be used to determine or predict the persistence, toxicity or bioaccumulating tendency of a chemical (see Chapter 4).

7.3 CONTROL TECHNOLOGIES

For existing persistent toxic substances, treatment or control technologies can be used to limit or virtually eliminate their release into the environment. This reliance on controls will be needed, in some cases, to bridge the gap between the phaseout and full implementation of a sunsetting program. In other cases, the decision to rely on advanced control or treatment technologies may be made to allow continued uses of a process involving the reliance on, or production of a persistent toxic substance. In this event, the application of advanced technology becomes a tool that provides for virtual elimination (or prevention) of release of the persistent toxic substance to the environment.

7.4 PROCESS TECHNOLOGIES

Pollution prevention approaches, which include the substitution of new process technologies or use of alternative materials within existing technologies, can result in virtual elimination of persistent toxic substance formation. In this event, the ability to manufacture a product and/or the viability of an industry is preserved while the need to deal with the persistent toxic substance is addressed. An important aspect of applying substitute technologies or materials is the need to evaluate alternatives to ensure that the new process or alternative materials do not result in the same or greater degree of injury or risk to the environment or to its denizens, including humans. Additionally, replacement technologies must be given adequate development time in which they become proven before their use can be applied in wholesale fashion. Finally, decisions regarding the application of replacement technologies must be made by or in full consultation with the affected industry. These operators have the best understanding of their processes and which changes will accomplish the desired result.

7.5 REMEDIATION TECHNOLOGIES

In several cases, the largest contribution of persistent toxic substances to the environment is from existing deposits that have resulted from previous human activities. Virtually eliminating these existing storehouses may require the application of several different types of technologies, many of which already exist. However, their application is impeded by social, political and/or regulatory barriers.

The choice of technology to be employed for remediation depends on case-by-case circumstances. Technologies that rely on capping or otherwise isolating materials in place may be best in some situations. In others, relocation to a more secure repository or destruction may be preferred. In all cases, it is necessary to determine, in advance, that the technology provides a significantly greater degree of environmental protection than the original situation. The best option, for some cases, may be to not disturb the deposit and let "natural" processes run their course.

For many remediation efforts, it is necessary to overcome the phobia regarding remediation/disposal methodology. Everyone's "back yard" will become cleaner if the objections and arguments regarding siting of remediation/destruction facilities are set aside, to allow for swift, fair evaluations of remedial options such that cleanup can begin.

7.6 CONCLUSIONS AND RECOMMENDATIONS

Attaining the virtual elimination goal is a long-term effort. The practical limitations and effectiveness of the technological options, costs, priorities in a resource-limited society, and relative risks all must be considered. Technologies can be employed and developed which will result in environmental improvements and lead to virtual elimination. The key to success is the approach. To argue over which technology choice removes the last molecule of a persistent toxic substance from a source and not make reasoned choices based on these realities is counterproductive to the virtual elimination goal.

Technology offers valuable tools and opportunities to move toward the virtual elimination goal. The Task Force recognizes that a variety of technologies are or will shortly become available, for instance, to deal with contaminated sediment. The Task Force particularly urges the application of technology:

- To modify production processes so as to prevent the creation of persistent toxic substances in the first place.
- To remediate contaminated sediment, groundwater, and other locations where persistent toxic substances are in the ecosystem.
- To destroy existing stocks of persistent toxic substances, including those in hazardous waste facilities and other storage sites, once and for all.

The Virtual Elimination Task Force recommends that:

12. The Parties promote development of technologies -- products and processes -- that will eliminate the creation of persistent toxic substances and thereby eliminate their input to the Great Lakes Basin Ecosystem.

13. The Parties inventory existing stocks of destructible persistent toxic substances and apply destruction technology to eliminate these stocks.

9. THE ROLE OF COMMUNICATION, EDUCATION, AND CONSULTATION

9.1 COMMUNICATION AND EDUCATION

For successful development and implementation of a virtual elimination strategy, the need for action must be understood and supported by all stakeholders. Communication and education have key roles to play if understanding of the need for virtual elimination of persistent toxic substances from the Great Lakes, and support for the societal changes implicit in this elimination, are to be created.

For virtual elimination of persistent toxic substances from the Great Lakes to be achieved, all stakeholders must:

- Become aware of the problems and risks involved with these substances.
- Understand the need to develop and use industrial processes that employ non-toxic substitutes. Where these cannot be developed, or can be developed only over the long term, stakeholders will need to reach consensus on whether to retain a persistent toxic substance for its benefits or do without the substance and its benefits.
- Be committed strongly enough to achieving virtual elimination to generate the consumer adaptability, stakeholder cooperation and political will necessary to bring it about.

Educational initiatives must be developed to address these three objectives. In addition to communicating information, such initiatives should provide a model for environmental decisionmaking, create an informed constituency for virtual elimination, and foster public demand for environmentally benign products and production processes. The Commission's *Fifth* and *Sixth Biennial Reports* recommended several specific initiatives to incorporate environmental issues and information into the school curriculum (2,3). These reports, together with the Commission's *Special Report on Great Lakes Environmental Education*, (50) provide a foundation of educational initiatives to support the objectives of the virtual elimination strategy outlined in this report.

The specific school-level and adult education programs based on this foundation should be shaped by several considerations.

- First, since both children and adults participate more fully in education that relates to their own interests and concerns, the educational materials should focus on topics such as water quality, climate, energy consumption, transportation options, and consumer choice. Similarly, issues relevant to each community and region should be examined from a local perspective as well as from a basinwide context. Instruction and practice in decisionmaking that involves tradeoffs should be a central element of these educational initiatives.
- Second, because many teachers feel inadequately prepared to instruct students on environmental topics or to encourage their exploration and analysis of real-world case material, resources are needed to provide appropriate training workshops and materials for teachers. As an example, the KEY (Knowledge of the Environment for Youth) Foundation provides for development of such material.
- Third, school-level educational initiatives should be planned to involve parents and the larger school community, building on the fact that children and young people bring new ideas from school to home. Ideally, resources would be made available for all schools, colleges and universities in the Great Lakes basin to foster broad participation in community risk-benefit analyses and goal-setting exercises. Involvement would be sought from business and industry, labour unions, service and cultural organizations, environmental groups and the news media. A central element in these exercises would be the development of local long-range action plans to implement a virtual elimination strategy for their community and for the basin.

Examples of educational mechanisms and programs are given in Table 6.

A key element of a virtual elimination education program should be the provision of information to the public.

- Information must be made available on the full range of risks and benefits associated with all products and production processes (including agriculture) that involve persistent toxic substances, which could reach the Great Lakes via any medium. With this information in hand, people could examine and discuss the costs and benefits (tradeoffs) involved in redesigning production processes and/or doing without some products, as would be required if the manufacture and/or use of some or all persistent toxic substances were banned.

- Regular reports must be made to the public on the extent to which progress toward the virtual elimination of persistent toxic substances, by sector, was on schedule. This would provide for accountability in implementing the strategy.

Overall, the communication and education component of the virtual elimination strategy should enable people to:

- Understand the problems, solutions and tradeoffs involved, i.e. function as informed consumers aware of possible lifestyle implications.
- Access relevant information, especially regarding product selection.
- Monitor problems in all sectors: industrial, agricultural, commercial, municipal, institutional, and residential.
- Bring pressure for improvements in all sectors.

With these goals in mind, the Virtual Elimination Task Force recommends that:

15. The Commission reinforce its commitment to its recommendations concerning awareness and education [expressed in its *Fifth* and *Sixth Biennial Reports* and its *Special Report on Great Lakes Environmental Education*] by again recommending their implementation to the Parties.

16. The virtual elimination strategy include provision for education initiatives at the local and regional level, particularly initiatives to encourage communitywide participation in local activities to eliminate the input of persistent toxic substances into the ecosystem.

Community advisory panels modelled after the public advisory committees associated with the Remedial Action Plans would be an excellent way to obtain involvement in the development of such initiatives.

9.2 CONSULTATION AND DIALOGUE

A consultative approach to developing a virtual elimination strategy is required to obtain the professional and public input necessary to ensure that implementation of the strategy is feasible and there is a broad-based commitment to action.

Consultation and dialogue foster consensus building and partnership activities among the many stakeholders that must be involved in effective, efficient achievement of virtual elimination. In turn, consensus can lead to the voluntary remedial and preventive actions that are a desirable and necessary complement to regulatory measures. Voluntary actions developed from consultation and dialogue encourage "win-win" solutions in which concerned groups have their interests addressed and producers are able to accommodate these concerns in the most cost-effective manner. Such voluntary initiatives are essential to successful implementation of the virtual elimination strategy because the social and monetary transaction costs of effecting controversial change solely through legislation are becoming unacceptably high.

Table 6
Educational Mechanisms and Programs

- Toxic Release Inventory (United States) & National Pollutant Release Inventory (under development in Canada): school, community monitoring
- Water quality monitoring: programs in Great Lakes basin schools
- Industry-community advisory panels (such as the Dow initiatives)
- Growing Green farm programs to reduce persistent toxic substances use
- Green Product/Green Process Guide to persistent toxic substances-free shopping, living
- Labour education: right-to-know about persistent toxic substances in the workplace, to refuse unsafe work, to report polluting actions
- Involvement of native people regarding fish consumption, drinking water
- "Success story" case studies that recognize progress
- Household hazardous waste education and effective collection programs
- Industry self-education: e.g. highly trained experts to initiate process redesign throughout an industry
- Access to information on persistent toxic substances use, discharge, pathways and cleanup in relation to renewal of permits to discharge
- Global outreach: city to city, union to union, industry to industry technology transfer

Consultative approaches should also be used by the Parties to develop the legislation, regulations and schedules that underpin the strategy for virtual elimination. Obtaining input from all stakeholders can assure feasibility of the resultant legislation and promote commitment to its timely implementation. New partnership initiatives should include cooperative efforts to explore employment creation in the fields of pollution prevention and remediation.

Mechanisms such as the Great Lakes Remedial Action Plan programs, Canadian provincial Round Tables, "Good Neighbour" Community Agreements with local industries, the New Directions Group (chemical industry and environmental groups), "white papers" on proposed programs with followup workshops, and meetings with labour and the general public to discuss local options for action are all appropriate vehicles to establish communication among stakeholders and offer access to experts in the field.

Whatever the mechanism chosen, effective consultation requires mutual respect among participants and equal access to information for all. It is important that consultation and dialogue initiatives -- whether two-party or multistakeholder and whether initiated by governments, the private sector or nongovernmental organizations -- be undertaken in good faith, with the full intention of giving serious attention to the concerns of all participants. To do otherwise is to destroy consultation as a legitimate process. When consultation is successful, an important outcome is the highly effective consensual problem solving that results from a genuine understanding of others' concerns and viewpoints. This type of interaction can lead to decisions being made by the responsible parties that address societal needs as well as stakeholders' own concerns.

With these goals in mind, the Virtual Elimination Task Force recommends that:

17. **The Parties highlight and adopt consultation and dialogue as the key components for the validation and implementation of the virtual elimination strategy, and provide sufficient resources for design and implementation of the consultation process.**

18. **The Parties establish formal and regular opportunities for ongoing stakeholder consultation, as part of the virtual elimination strategy.**

[illegible]

Consultative approaches should also be used by the Parties to develop the legislation, regulations and schedules that underpin the strategy for virtual elimination. Obtaining input from all stakeholders can assure feasibility [illegible] and promote [illegible] implementation. [illegible] partnerships [illegible] efforts to explore employment creation in the fields of pollution prevention and remediation.

Mechanisms such as the Great Lakes Remedial Action Plan programs, Canadian provincial Round Tables, Good Neighbor Community Agreements with local industries, the New Directions Group (chemical industry and environmental groups), white paper consultative programs with industry associations, and meetings with labor and the general public to discuss local options for action are all important vehicles to establish communication among stakeholders and offer advice to experts in the field.

Whatever the mechanism chosen, effective consultation requires mutual respect among participants and equal access to information for all. It is important that consultations and dialogue processes, whether two-party or multi-stakeholder, whether initiated by governments, the private sector or nongovernmental organizations, be conducted in good faith, with the full intention of giving serious attention to the concerns of all participants. To do otherwise is to destroy the credibility of the entire process. When consultation is successful, an important outcome is the highly effective consensual problem-solving that results from a genuine understanding of others' concerns and constraints. This type of interaction can lead to decisions being taken by the community at large that address societal needs as well as environmental concerns.

With these goals in mind, the [illegible] Task Force recommends that:

17. The Parties highlight and make visible the use of dialogue as the key instrument for the collaborative implementation of the virtual elimination strategy, and provide sufficient resources for design and implementation of the consultation process.

18. The Parties and the [illegible] Parties for ongoing stakeholder [illegible] support of the virtual elimination strategy.

10. INDICATORS TO MONITOR PROGRESS

The ultimate goal for virtual elimination of persistent toxic substances is to obtain and maintain a Great Lakes environment within which aquatic organisms, and those that feed on those organisms (including humans), are no longer adversely affected by these substances. Thus, significant milestones leading to the achievement of this goal must be identified, assessed, and incorporated into the elements of the virtual elimination strategy. A suite of indicators that measure persistent toxic substances -- their input, presence, and the injury they have caused -- must be clearly identified.

Specifically, indicators are needed in a virtual elimination context to:

- Establish the current status of the Great Lakes Basin Ecosystem in regard to inputs and loadings of persistent toxic substances and in regard to impact on ecosystem health resulting from present contaminant levels in the ecosystem.
- Track progress toward virtual elimination of persistent toxic substances within the Great Lakes Basin Ecosystem, i.e. trends over time.
- Demonstrate that virtual elimination of persistent toxic substances has been achieved and that ecosystem health is no longer impaired by them, i.e. ecosystem integrity and absence of biological injury.
- Ensure long-term protection of the ecosystem from persistent toxic substances after successful restoration.

This necessitates appropriate surveillance and monitoring programs to ensure that the requisite data and information are provided. End points must be defined and quantified in terms of absence of injury, restoration and protection of uses. For example, as part of the Remedial Action Plan program, guidelines have been established to quantify each use impairment identified in Annex 2 of the Agreement, to determine when these uses are no longer impaired and have been restored (51,52). For the PCB and mercury case examples discussed in Appendix A, a mass balance model is used to project the extent of ecosystem restoration possible (see also Chapter 5).

There are various categories of indicators. For example:

- Inventory data. Information about the production, use, release, storage, and disposal of persistent toxic substances provides benchmarks to reduce and eliminate loadings to the ecosystem and to reduce the quantity of waste produced.
- Physical and chemical measurements of contaminant levels in the ecosystem.
- Measurements of the biological injury caused by contaminants within the ecosystem.
- Socio-economic indicators.

10.1 INVENTORY DATA: PRODUCTION, USE, RELEASE, AND DISPOSAL

In the short term, emphasis should be placed on information about the quantities of chemicals produced, used, stored, released, and disposed of, to provide benchmarks to reduce and eliminate loadings to the ecosystem and to reduce the quantity of waste produced, as called for in Annex 12 of the Agreement. This information will monitor progress toward achieving the virtual elimination goal. Specifically, data on releases should include quantitative information about aqueous discharges and atmospheric emissions. The production and use inventory should include information about the method of storage and disposal, as well as the quantities involved. Release or loading data also can be correlated with concentrations observed in the ecosystem, which can be used to estimate the time required to achieve a change in ecosystem concentration, in response to a load reduction. The correlation can be established through a mass balance model, which is presented in Chapter 5. Figure 6 presents examples of expected ecosystem improvement in response to reductions in PCB loads to Lake Superior.

10.2 PHYSICAL AND CHEMICAL MEASUREMENTS

The environmental samples that provide the most useful information are sediments, fish and terminal predators in aquatic food chains. Persistent toxic substances accumulate in sediments and in fish to several orders of magnitude greater than in water. In addition, benthic samples can be used to assess bioavailability of contaminants from sediment. Benthic organisms serve as a source of food and contaminants for other species higher in the food chain. Fish and fish-eating birds, as terminal predators, are also efficient accumulators of persistent toxic substances.

Chemical contaminant levels in water, biota, sediment, and air and the physical conditions in the Great Lakes Basin Ecosystem have been monitored for several years. Such monitoring should be continued, but needs to be more coordinated among the various government agencies than at present.

In addition to regular sampling of Great Lakes water, biota, sediments, and air for analyses, tissue archiving and specimen banks should be significantly augmented. A *Great Lakes Regional Specimen Bank Feasibility Study* (32), completed in 1992, described desirable characteristics of a specimen banking program. Archiving and specimen banking would provide historic samples to document changes and retrospectively determine trends in the Great Lakes environment, especially as improved analytical procedures are developed. In addition, retrospective trends can be established for those chemicals that have only been identified more recently as being responsible for ecosystem injury.

10.3 MEASUREMENTS OF BIOLOGICAL INJURY

Toxicity is an integrated biological response to exposure to a host of chemicals in an organism's environment. Chemical measurements tell us about the presence of contaminants in water, sediment, air, and biota, but toxicity cannot be assessed merely by identifying and quantifying chemicals in these environmental media. Bioindicators are used to assess toxicity. They also provide a reliable measure of our progress toward the virtual elimination goal, rather than the attainment of some calculated target concentration.

Based on the proceedings of a workshop on bioindicators for virtual elimination of persistent toxic substances sponsored by the Task Force (31), bioindicators have been identified that can measure progress toward, and achievement of the virtual elimination goal. A bioindicator is an organism and/or biological process whose change in structure, function or activity points to changes in the integrity of the quality of the environment. These include:

- Indicator species, i.e. organisms whose biological characteristics make them suitable for quantitative measurement of changes in structure or function, or whose presence/absence may reflect certain environmental conditions.

- Biochemical markers, i.e. biochemical reactions that measure changes in cellular or subcellular processes within individual organs/tissues within an organism.

- Biological end points, which are measurable changes in the development, behaviour, reproductive success, or survival of the species.

These measurements become bioindicators when they help to establish or demonstrate a linkage between a persistent toxic substance and injury in a biological species. Examples of specific effects of persistent toxic substances in selected indicator species are summarized in Table 7. See also Appendix D.

10.4 SOCIO-ECONOMIC INDICATORS

Many social and economic indicators are difficult to measure and quantify and are often subjective in nature. However, some examples are presented below that could reflect changes in Great Lakes water quality.

In the area of human health, improvements in worker health and safety could be measured in terms of fewer absences related to exposure to persistent toxic substances, fewer chronic illnesses and long-term disabilities and, possibly, therefore, lower medical care and insurance costs over the long term for the private sector.

The Great Lakes fishery, with improved ecosystem quality, would produce more edible fish. This would encourage more recreational fishing, a possible revival of the commercial fishery and, thus, increased revenues from the fishery. A Great Lakes database of commercial fish catch trends is available at the U.S. Fish and Wildlife Service. Increased consumption of fish could be measured and examined as a source of better nutrition. This effect would be particularly important for native peoples and other subsistence fishers who depend on the fishery for a substantive portion of their diet, and for others who might wish to benefit from commercial use of the fishery.

Fewer unplanned releases of persistent toxic substances would be a measurable indicator that could be linked to lower cleanup costs, lower costs for water supply replacement for affected communities and although probably not measurable, less stress for those community residents who would no longer have to worry about the short- or long-term contamination of their water supply.

More private sector activity and person-hours of work would be created by the proliferation of remediation industries (short-term), and new industries (long-term) to develop products/processes free from persistent toxic substances, as prevention and zero use of such substances became the norm. Industries would close loops, finding economic uses for what were previously "wastes." Additional socio-economic indicators could include, for example, reductions in the number of waste sites, the number of exceedances of fish consumption guidelines, the loss of beneficial uses, and perception of risk. Further discussion of economic and societal considerations is presented in Chapters 8 and 9, respectively.

Table 7
Effects of Persistent Toxic Substances in Selected Indicator Species

		EFFECT	
PERSISTENT TOXIC SUBSTANCE	**INDICATOR SPECIES**	**BIOLOGICAL END POINT**	**BIOCHEMICAL MARKER**
DDT, DDE	Bald eagle Double crested cormorants	Eggshell thinning Feminization Adult mortality Embryo growth retardation	P-450 (other than EROD) Thyroid hyperplasia
Dieldrin	Bald eagle	Embryo mortality Adult mortality	P-450 (other than EROD) Thyroid hyperplasia
PCB, dioxin	Bald eagle Forster's tern Double crested cormorants Snapping turtle Herring gull	Embryo mortality Embryo deformities Poor hatching (avians) Feminization	Caffeine breath test Porphyria Vitamin A depletion Thyroid hyperplasia EROD induction
	Mink Otter Lake trout	Reproduction dysfunction	
	Human offspring	Neurobehavioural deficits Low birth weight	Caffeine breath test
PAH	Brown bullhead White sucker	Liver & skin tumours	EROD induction DNA adducts & damage Bile
Lead	Fish Waterfowl Human offspring	Hyperactivity Permanently reduced intelligence Neurobehavioural abnormalities	Altered porphyria patterns ALAD inhibition
Mercury	Fish-eating birds	Altered reproductive behaviour	Altered porphyria patterns
	Human offspring	Learning & motor skill deficits Neurotoxicity	

Note: EROD = Ethoxyresorufin-0-deethylase
ALAD = Aminolevulinic acid dehydratase
P-450 = Cytochrome P-450
PAH = polynuclear aromatic hydrocarbon

10.5 MEASUREMENT OF THE SUCCESS OF THE VIRTUAL ELIMINATION STRATEGY

Figure 7 shows a protocol for measuring the success of virtual elimination of persistent toxic substances in the Great Lakes and for monitoring the integrity of the ecosystem over time after successful restoration.

In a regularly scheduled assessment, short- and long-term monitoring is conducted. Indicators for short-term monitoring could include inventory data such as commercial production/use volume and release data; physical measurements such as pH and conductivity; chemical measurements of the persistent toxic substances in water, sediment, air, and biota; and bioindicators such as biomarkers (P-450, DNA adducts and damage, porphyria, and Vitamin A depletion) and short-term bioassays (ceriodaphnia, algae). For long-term monitoring, indicators could include the same inventory data and physical and chemical measurements. In terms of bioindicators, biological endpoints such as eggshell thinning, reproductive failures, presence of tumours and other abnormalities can be documented. In addition, socio-economic trends can be observed as the virtual elimination strategy is implemented.

If conditions in the Great Lakes Basin Ecosystem are acceptable, no further monitoring is necessary except for routine assessment. If ecosystem conditions are unacceptable, more rigorous monitoring is launched in order to identify and remediate the problem. The success of such a remediation project is monitored by physical and chemical measurements (such as those mentioned above) along with a host of bioindicators. The bioindicators consist of examination of biological endpoints for the most sensitive species (e.g. the bald eagle and double crested cormorants). Monitoring is augmented by regularly conducted long-term assessments. If the problem is transient, no remediation is necessary and long-term monitoring is reinforced.

10.6 CONCLUSIONS AND RECOMMENDATION

Appropriate indicators are necessary to measure the success of the strategy to virtually eliminate persistent toxic substances and to ensure the long-term protection and integrity of the Great Lakes ecosystem.

- Chemical indicators are required to measure concentration levels of persistent toxic substances in the ecosystem.

- More importantly, bioindicators are required to measure toxicity and the injury or absence of injury to living organisms in the ecosystem.

- The indicators chosen should be based on sound science, consider socio-economic factors, and provide an accurate and sensitive "barometer" to indicate the success of the virtual elimination strategy.

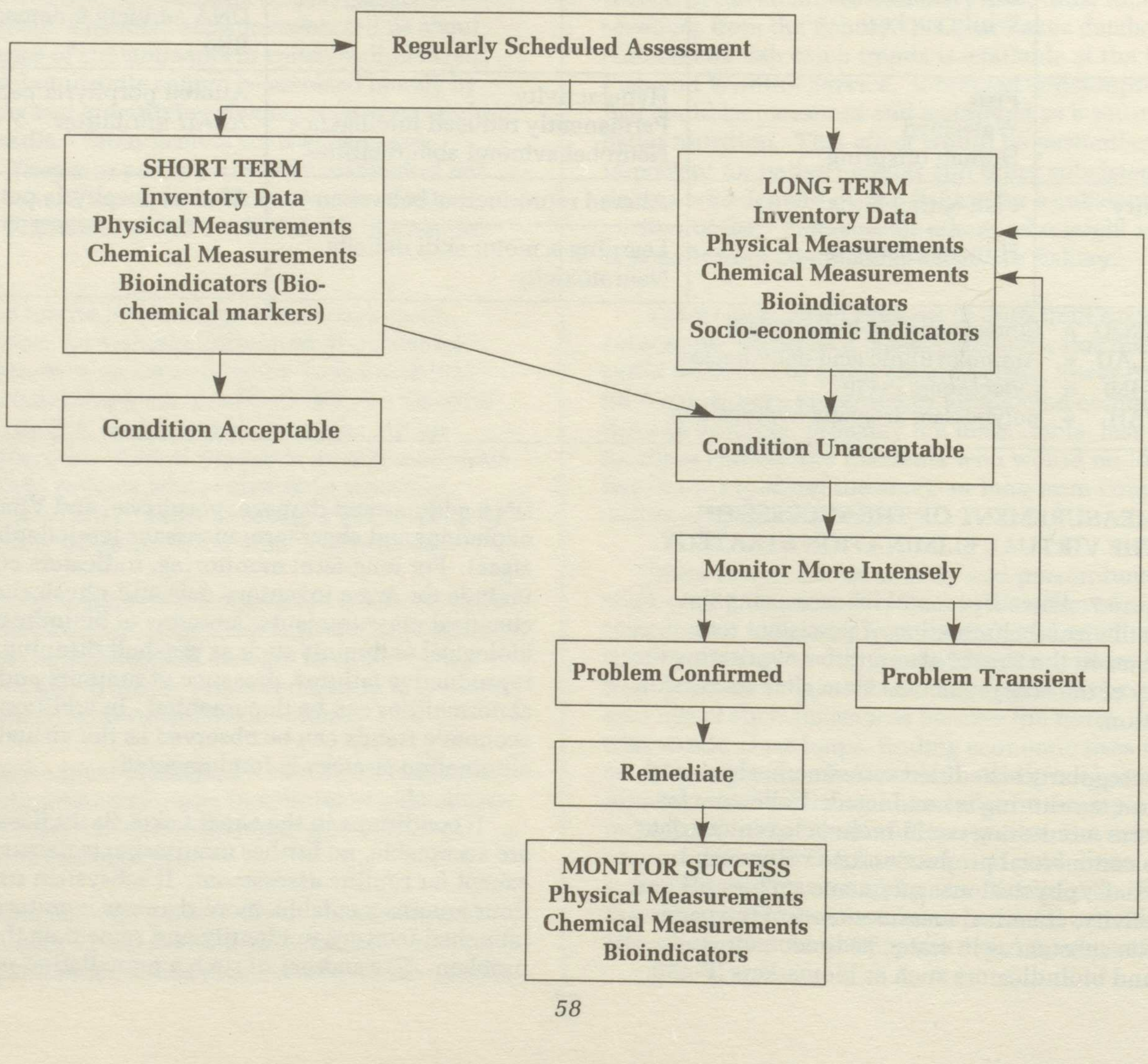
The Virtual Elimination Task Force recommends that:

19. The Parties adopt, as part of their regular monitoring efforts:

- indicators that measure the concentration levels of persistent toxic substances in the ecosystem.

- coordinated bioindicator monitoring programs that measure toxicity and the occurrence or absence of injury to living organisms.

Figure 7
Protocol for Use of Indicators in a Virtual Elimination Strategy



CONCLUSIONS AND RECOMMENDATIONS

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 THE STRATEGY

The Virtual Elimination Task Force articulated a simple vision regarding persistent toxic substances: ecosystem integrity, characterized by a clean and healthy Great Lakes Basin Ecosystem and by the absence of injury to living organisms and to society. The challenge is to achieve this vision. As a society, we have not yet virtually eliminated the input of persistent toxic substances to the ecosystem, and injury to living organisms continues to occur. To develop an effective strategy to achieve virtual elimination and an absence of injury, the Task Force asked the question, What must we do to eliminate injury attributable to persistent toxic substances?

The Task Force recognizes that progress has been made to reduce the input to, and the impact of persistent toxic substances on the Great Lakes. This is evidenced, for example, by trends in PCB levels in fish from Lake Ontario and Lake Superior. In addition, a number of recent initiatives such as Canada's ARET (Accelerated Reduction and Elimination of Toxics) process and the binational Lake Superior Program should lead to further progress.

From its deliberations, the Task Force concluded that many principles of past pollution-response practices are not appropriate when dealing with persistent toxic substances. The Task Force also observed an evol-ution in thinking, from control, to prevention, toward sustainable industry and product/material use. Consequently, the Task Force has articulated the essential principles and components of a strategy to virtually eliminate the input of persistent toxic substances to the ecosystem, and has also developed a decisionmaking process for implementation of that strategy. The Task Force believes that implementation of the strategy will achieve the Task Force's vision and the Agreement's virtual elimination goal.

Therefore, the Virtual Elimination Task Force recommends that:

1. **The Commission and the Parties adopt the vision: ecosystem integrity, characterized by a clean and healthy Great Lakes Basin Ecosystem and by the absence of injury to living organisms and to society.**

2. **The Commission and the Parties immediately adopt the Task Force's strategy to virtually eliminate the input of persistent toxic substances to the ecosystem, including its fundamental principles and components and the decision-making process to implement the strategy.**

The Task Force has also developed a series of supporting recommendations that will facilitate implementation of the strategy, achieve virtual elimination of inputs and the absence of biological injury, while remaining responsive to social and economic realities. These are presented below.

11.2 CHEMICAL SELECTION

In order to focus a virtual elimination strategy on the correct substances, experts from academia, governments, industry, and other stakeholders collectively must:

- Identify criteria for use in the chemical selection and phaseout processes, and adopt uniform quantitative values for each criterion.
- Develop and recommend a uniform screening procedure to identify chemicals that meet the definition of persistent toxic substance and to schedule their phaseout.
- Develop and recommend a uniform agreed-upon procedure, preferably incorporating the use tree and life cycle approach described in Chapter 3, to select persistent toxic substances for phaseout.

The Task Force concludes that four criteria -- bioaccumulation factor (BAF); persistence; chronic toxicity to aquatic organisms; and evidence of specific causality and/or injury to biota -- are the most important in the selection and classification process. The Task Force has also proposed numerical values for BAF, persistence, and chronic toxicity, to be applied for initial screening of substances, as well as more stringent values to be applied to identify those chemicals that meet the definition of persistent toxic substance and which should be virtually eliminated.

The Virtual Elimination Task Force recommends that:

3. **The Parties, in consultation with stakeholders, jointly develop, quantify, and apply criteria to screen chemicals, which will lead to development of a list of persistent toxic substances to be evaluated through the decisionmaking process, and to select persistent toxic substances for phaseout.**

Since considerable work has already been undertaken to identify and develop the basis for selection criteria, the Task Force believes the criteria can be confirmed and quantified within six months after release of this report. As a point of departure, the Parties should give serious consideration to the criteria and numerical values proposed in Chapter 4. They should also closely examine chemical classes and processes as well as industry sectors related to the generation and use of persistent toxic substances.

11. 3 TIMING

In some cases, immediate sunsetting is feasible, for example, because alternatives to the particular persistent toxic substance or to a particular production process are available. However, this is not always the case. Therefore, a specific timetable should be established for the phaseout of targeted persistent toxic substances, which would allow industry and the research community an opportunity to develop suitable alternatives. The timetable should also include benchmarks to demonstrate progress toward complete phaseout.

The Virtual Elimination Task Force recommends that:

4. **The Parties set specific timetables for the phaseout of persistent toxic substances not amenable to an immediate ban.**

Particular attention should be focused on those persistent toxic substances which are responsible for injury to the ecosystem.

11.4 IMMEDIATE ACTION

Notwithstanding the development of selection criteria, a screening process, and a list of persistent toxic substances, the Virtual Elimination Task Force concludes that sufficient evidence exists to warrant immediate phaseout of the 11 Critical Pollutants identified by the Water Quality Board in 1985 (Table 1). All 11 substances are persistent and cause such serious injury to living organisms that any entry into, or presence in the ecosystem is unacceptable. The Task Force notes that the 11 Critical Pollutants have, in effect, already been subjected to evaluation, as called for in the virtual elimination strategy. They appear on most, if not all, toxic chemical lists. All are subject to regulation, and actions taken over the past 20 years have significantly reduced ecosystem concentrations. However, levels in the ecosystem continue to be elevated. The Task Force believes that application of the strategy and its decisionmaking process, presented in Chapter 3, will achieve virtual elimination of these persistent toxic substances.

The Virtual Elimination Task Force recommends that:

5. **The Parties, through application of the decisionmaking process, immediately initiate measures to sunset the 11 Critical Pollutants, including all aspects of their manufacture, import, export, use, and disposal.**

The Task Force is aware of the myriad of issues that must be faced and resolved to fully sunset the 11 Critical Pollutants. Among these are continued use and disposal practices, remediation, foreign use, long-range atmospheric transport, and natural occurrence. If we are serious about virtual elimination and fulfilling the requirements of the Agreement, these and other similar questions must be resolved. The use tree and life cycle approach presented in Chapter 3 is an appropriate mechanism within which to consider confounding factors. Appendix A presents further discussion of the problems and factors to consider, and the measures that can be taken when dealing with two of the Critical Pollutants, PCB and mercury.

11.5 GLOBAL CONSIDERATIONS

The Task Force notes that large quantities of some persistent toxic substances (such as DDT), although "banned" for domestic use in the United States and Canada, are still produced in the United States for export, as well as produced and used in a number of other countries. While charged to investigate the Agreement requirement to virtually eliminate the input of persistent toxic substances to the Great Lakes Basin Ecosystem, the Task Force concludes that a Great Lakes regional focus is clearly insufficient. The virtual elimination strategy must be applied globally, because of the ability of persistent toxic substances to disperse globally, in large measure through long-range atmospheric transport.

Because of their knowledge and experience with persistent toxic substances, the Great Lakes governments must take a leadership role to implement the strategy globally. To assist in this endeavour, the Virtual Elimination Task Force recommends that:

6. **The Commission, in partnership with Great Lakes governments, convene an international conference to focus on international implementation of the virtual elimination strategy.**

The biological injury caused by the 11 Critical Pollutants can serve as a focus to actively promote the need for the strategy, as well as the means necessary to achieve virtual elimination. The conference can also serve as a forum to obtain quantitative information about the amounts of persistent toxic substances presently in use globally.

11.6 DATA AND INFORMATION: NEEDS AND MANAGEMENT

Information about sources and pathways by which persistent toxic substances enter the ecosystem, and the associated quantities, is required for implementation of the virtual elimination strategy. Information is also required about the life cycles of persistent toxic substances, their precursors, and the quantities used, released, in storage, and disposed of. Accurate and consistent information about the relative and absolute contributions from various sources and pathways provides an accurate baseline against which to measure progress. Such information also helps to prioritize reduction and elimination programs. This information must be available not only for Canada and the United States, but also internationally.

Sources and pathways include municipal and industrial effluents; surface runoff; combined sewer overflows, storm sewers, and treatment plant bypasses; emissions to the atmosphere; contaminated sediment; groundwater; and spills from ships and shore-based facilities. The Task Force concludes that information about sources and pathways and the associated contaminant quantities is inadequate. The Virtual Elimination Task Force recommends that:

7. **The Parties enhance programs to identify sources and pathways and to quantify loadings of persistent toxic substances to the Great Lakes Basin Ecosystem.**

8. **The Parties compile reliable and complete quantitative information for the life cycle of persistent toxic substances and their precursors.**

This information must include, as a minimum, the amounts of persistent toxic substances produced, used, released, and disposed of, as well as their fate in the ecosystem. Further, the information must be integrated and must be readily accessible by the public.

Particular emphasis must be placed on the atmosphere, the dominant pathway by which many persistent toxic substances reach the Great Lakes. Since sources within and outside the basin contribute, the virtual elimination strategy cannot be confined to the Great Lakes basin. The Virtual Elimination Task Force recommends that:

9. **The Parties develop quantitative information about the release of persistent toxic substances <u>to</u> the atmosphere from all sources.**

This information must include the form and speciation of the substances being emitted. Further, the information base must be sufficient to determine and differentiate the impact of local versus distant sources of persistent toxic substances, including identification of major sources and source categories.

The institutional framework to assemble integrated information on persistent toxic substances must be improved. Historic data collection programs generally aimed at conventional pollutants and nutrients. Current programs do not necessarily differentiate between toxic substances and persistent toxic substances. These need to be redirected to focus on persistent toxic substances, and to better address such issues as public access, confidentiality, levels of detection, and timely reporting.

The United States Toxic Release Inventory (TRI) and STORET (Storage and Retrieval Information System) are two complementary programs that can contribute to the assembly and management of persistent toxic substance data, and to the development of integrated information. The concept of an inventory of releases of persistent toxic substances should be expanded to Canada. Canada's National Pollutant Release Inventory, now under development, should be compatible with the U.S. TRI. Both should be comprehensive and apply to all source sectors. Further, reporting thresholds should be lowered and products (including inadvertently produced pollutants) accounted for.

A comprehensive database and integrated information about persistent toxic substances would underpin a decision-support system that could be used, for instance, to identify and substantiate remedial actions, with associated schedules and priorities; project future loadings and concentrations of persistent toxic substances, in the form of agreed-to targets towards virtual elimination; and facilitate assessment of the effectiveness of programs undertaken pursuant to the Agreement.

11.7 MASS BALANCE ECOSYSTEM FATE MODELS

Mass-balance ecosystem-fate models are valuable tools for a virtual elimination strategy. Existing models are accurate enough to estimate contaminant fate now, and in the future, as remedial measures are implemented. The models can be used to project future ecosystem concentrations and response times, as a result of reduced inputs of persistent toxic substances to the ecosystem. Models can also be used proactively to identify new pollutants and future problems. The Virtual Elimination Task Force recommends that:

10. **The Parties use mass balance-ecosystem fate models as tools in the virtual elimination strategy not only for contaminants of present concern, but also proactively to identify new pollutants and future problems.**

Improved source information and a better understanding of physical, chemical, and biological processes that control contaminant fate in the lakes would improve projections of the rate and extent of ecosystem response.

11.8 LEGISLATION, REGULATIONS, AND PROGRAMS

The Virtual Elimination Task Force concludes that governments have the legal authority to implement the virtual elimination strategy, but have not acted on their authority. As described in Chapter 6, the Task Force has identified gaps and impediments that hinder achievement of virtual elimination, but a number of short- and long-term reforms could help to realize the virtual elimination goal.

The Virtual Elimination Task Force recommends that:

11. The Parties review their legal framework for dealing with persistent toxic substances and, if necessary, promulgate legislation to remove barriers and to promote implementation of the virtual elimination strategy.

The legislation should promote reduced use of persistent toxic substances, examination of product/material use, sunrise/sunsetting, and pollution prevention to reduce and ultimately eliminate creation of persistent toxic substances. The legislation should also promote establishment and conduct of programs that provide requisite data and information, as described above.

As part of the approval process for allowing releases to the ecosystem, releases must not be allowed to increase from present loadings. Future approvals must include reduced limits as part of the racheting down process toward virtual elimination, and approvals will only be given if use-reduction plans have been submitted for persistent toxic substances.

11.9 TECHNOLOGY

The Virtual Elimination Task Force recognizes the need to prevent the creation of persistent toxic substances or, if they have been created, to destroy them. Measures short of destruction, such as storage or disposal, do not close the loop on full life cycle consideration of persistent toxic substances, and could lead to future ecosystem contamination and biological injury. Technology offers valuable tools and opportunities to move toward the virtual elimination goal. The Task Force recognizes that a variety of technologies are or will shortly become available, for instance, to deal with contaminated sediment. The Task Force particularly urges the application of technology:

- To modify production processes so as to prevent the creation of persistent toxic substances in the first place.
- To remediate contaminated sediment, groundwater, and other locations where persistent toxic substances are in the ecosystem.
- To destroy existing stocks of persistent toxic substances, including those in hazardous waste facilities and other storage sites, once and for all.

The Virtual Elimination Task Force recommends that:

12. The Parties promote development of technologies -- products and processes -- that will eliminate the creation of persistent toxic substances and thereby eliminate their input to the Great Lakes Basin Ecosystem.

13. The Parties inventory existing stocks of destructible persistent toxic substances and apply destruction technology to eliminate these stocks.

Particular emphasis should be placed on PCBs.

11.10 ECONOMIC INSTRUMENTS

The Virtual Elimination Task Force investigated the potential usefulness of economic instruments (or "incentives") to help achieve virtual elimination of persistent toxic substances. With the assistance of a contractor, the Task Force endeavoured to design, evaluate, and propose a specific program of economic instruments for application in a virtual elimination context. Although the contractor has provided information, time constraints and other considerations precluded adequate Task Force consideration of the material received, as well as formulation of detailed conclusions and advice for the Commission.

The Task Force can nonetheless conclude that economic instruments are an important component of the virtual elimination strategy. However, the instruments selected, and their method of application to persistent toxic substances in a virtual elimination context, may well be different from the instruments (or incentives) used in the treatment, control, and remediation regimes for nonpersistent contaminants. Further investigation is required to identify the instruments and describe their application.

Even though it was unable to consider the economic material received, the Virtual Elimination Task Force recommends that:

14. The Commission undertake an investigation to identify appropriate economic instruments for use in a virtual elimination context, and to describe their application to virtually eliminate

the input of persistent toxic substances to the ecosystem.

11.11 COMMUNICATION, EDUCATION, AND CONSULTATION

Successful implementation of the virtual elimination strategy requires understanding and support by all stakeholders. Communication and education have key roles to play if understanding of the need for virtual elimination of persistent toxic substances, and support for societal change implicit in this implementation, are to be created. People must become aware of the problems and risks, and become strongly committed to effecting a solution. The Virtual Elimination Task Force recommends that:

15. **The Commission reinforce its commitment to its recommendations concerning awareness and education [expressed in its *Fifth* and *Sixth Biennial Reports* and its *Special Report on Great Lakes Environmental Education*] by again recommending their implementation to the Parties.**

16. **The virtual elimination strategy include provision for education initiatives at the local and regional level, particularly initiatives to encourage communitywide participation in local activities to eliminate the input of persistent toxic substances into the ecosystem.**

Community advisory panels modelled after the public advisory committees associated with the Remedial Action Plans would be an excellent way to obtain involvement in the development of such initiatives.

The Task Force supports multi-stakeholder consultation to identify the existence of problems and to implement solutions. Consultation and dialogue are essential to establish priorities, set goals, and define actions using the decisionmaking process. The Virtual Elimination Task Force recommends that:

17. **The Parties highlight and adopt consultation and dialogue as the key components for the validation and implementation of the virtual elimination strategy, and provide sufficient resources for design and implementation of the consultation process.**

18. **The Parties establish formal and regular opportunities for ongoing stakeholder consultation, as part of the virtual elimination strategy.**

11.12 INDICATORS TO MONITOR PROGRESS

Appropriate indicators are necessary to track progress toward the virtual elimination goal and to demonstrate ecosystem restoration and long-term protection and integrity. Chemical measurements provide information about the presence of contaminants in water, sediment, air, and biota, and bioindicators are required to assess toxicity. A bioindicator is an organism and/or biological process whose change in structure, function, or activity points to changes in the integrity of the quality of the environment. Bioindicators include indicator species, biochemical markers, and biological end points. The Virtual Elimination Task Force recommends that:

19. **The Parties adopt, as part of their regular monitoring efforts:**

    - **indicators that measure the concentration levels of persistent toxic substances in the ecosystem.**

    - **coordinated bioindicator monitoring programs that measure toxicity and the occurrence or absence of injury to living organisms.**

The indicators chosen should be based on sound science, consider socio-economic factors, and provide an accurate and sensitive "barometer" to indicate the success of the virtual elimination strategy.

11.13 POLYCHLORINATED BIPHENYL (PCB) AND MERCURY

The application of the virtual elimination strategy to PCB and mercury focuses on how to deal with persistent toxic substances that are known to cause injury, and have been the subject of intense action by government, industry, and others. Although ecosystem conditions have improved and biological injury has been reduced, injury is nonetheless still occurring.

Appendix A describes a wide range of actions necessary (but not sufficient) to virtually eliminate PCB and mercury from the ecosystem. Virtual elimination of these and other confirmed persistent toxic substances will not occur through reliance solely on treatment and control activities that are applied at the point of release. Prevention must be adopted and rigorously pursued to ensure that no additional quantities of PCB and mercury (those not already circulating in the ecosystem) are created, used, or released to the ecosystem. Current pollution prevention approaches, as applied by governments, will reduce, but not eliminate releases to the ecosystem. Concurrently, remediation of contaminated sediment, waste disposal sites, and other inplace sources of persistent toxic substances must take place.

To virtually eliminate PCB, a "banned" substance, the Virtual Elimination Task Force recommends that:

20. Governments and industry recover and destroy all existing stocks of PCBs in equipment, cease land disposal, and recover and destroy PCBs in sediment and landfills.

To virtually eliminate mercury, a substance with natural and anthropogenic sources, the Virtual Elimination Task Force recommends that:

21. Governments and industry reduce the use of fossil fuels with high mercury content, concurrently implement conservation measures to reduce electric demand and fuel consumption, phase out mercury use in consumer products, as well as mercury-based industrial processes, reduce mercury emissions from smelter operations, and recover (rather than dispose of) mercury in existing consumer and medical products.

For both PCB and mercury, the decisionmaking process presented in Chapter 3 should be used.

11.14 BASIC FEEDSTOCK SUBSTANCES

One debate within the Virtual Elimination Task Force was how to apply the virtual elimination strategy to a basic feedstock chemical and, more fundamentally, whether the strategy should be applied to a basic feedstock chemical. Appendix B provides perspective on this issue. The Virtual Elimination Task Force recommends that:

22. The Parties commission an exhaustive investigation that explores all factors and implications related to the implementation of the proposed sunsetting of a basic feedstock substance such as chlorine.

Such an investigation should be conducted with input and participation from all stakeholders, including industry, environmental and health experts, consumer and labour groups, special interest groups, and the general public.

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51. *Review and Evaluation of the Great Lakes Remedial Action Plan Program 1991.* Great Lakes Water Quality Board Report to the International Joint Commission, Windsor, Ontario, June 1991. 47 pp.

52. "Commission Approves List/Delist Criteria for Great Lakes Areas of Concern." *Focus,* Vol. 16, No. 1, March/April 1991, pp. 1-5.

53. U.S. Federal Government. "Office of Science and Technology Policy Risk Assessment Principles." *Federal Register,* Vol. 50, March 14, 1985. pp. 10371-10378.

LIST OF SUPPORTING REPORTS AND BACKGROUND DOCUMENTATION SUBMITTED TO THE VIRTUAL ELIMINATION TASK FORCE

[Note: Copies of all the following reports are available on request]

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G. Fisher, A.W. Andren and S.Wittman. *A Review of Selection Criteria Used to Assemble Toxic Chemicals Lists.* October 1992.

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D. Mackay, S. Sang, M. Diamond, P. Vlahos, E. Voldner, and D. Dolan. *Mass Balance and Virtual Elimination.* A Peer Review Workshop at University of Toronto, December 7-8, 1992.

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E. Pinkston. *Integrity of Hazardous Waste Disposal Sites: Recommendations for their Inclusion in a Strategy for Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin Ecosystem.* In preparation.

SEDIMENT

J.K. Bewtra, J.A. McCorquodale, N. Biswas, M. Siddique, and A. McCorquodale. *Virtual Elimination of Persistent Toxic Substances from Contaminated Sediment.* November 15, 1992.

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L. Botts and G. Paulson. *An Analysis of the Legislative and Regulatory Factors in a Virtual Elimination Strategy for Persistent Toxic Substances in the Great Lakes Basin Ecosystem.* March 1991.

I.W. Heathcote. *Policy and Regulatory Opportunities for the Implementation of Virtual Elimination in the Great Lakes Basin.* March 1991.

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ECONOMIC

P.A. Victor and P. Van Den Bergh. *Virtual Elimination of PCBs, Mercury, and Persistent Toxics from the Pulp and Paper Industry in the Great Lakes Basin: A Role for Economic Instruments?* June 28, 1991.

VHB Research & Consulting, Inc. *Economic Instruments and Virtual Elimination.* [Interim Report No. 1]. September 2, 1992.

VHB Research & Consulting, Inc. *A Program of Economic Instruments for Virtual Elimination of Persistent Toxins in the Great Lakes Basin.* Interim Report No. 2. September 17, 1992.

VHB-Hickling and AER◆X. *A Program of Economic Instruments for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin.* Preliminary draft, Report No. 4839-1, November 16, 1992.

VHB-Hickling ICF Resources, Inc. *Economic Instruments for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin.* Draft - Phase 2. Report No. 4839-3, July 8, 1993.

[Note: Additional reports are in preparation.]

INDICATORS

Bioindicators as a Measure of Success for Virtual Elimination of Persistent Toxic Substances. Proceedings of Indicators Workshop, held April 28-29, 1992. In preparation.

INDUSTRIAL

G.N. Werezak. *An Industrial Perspective on Virtual Elimination.* April 3, 1991.

PCB AND MERCURY
[Note: The following report comprises Appendix A]

J.A. Foran. *Application of the Virtual Elimination Strategy to PCB and Mercury.* June 17, 1993.

CHLORINE
[Note: The following three reports comprise Appendix B]

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D.K. Phenicie. *Virtual Elimination in the Pulp and Paper Industry.* January 7, 1993.

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